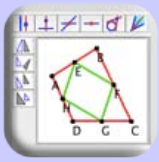
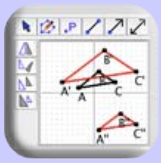
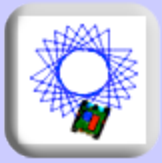
Core Math Tools

Link to help topics (below) by Mathematics Strand, Tool, or Feature *or* navigate the Help PDF (choose Info | PDF from the main tools page):

- Do a "search" using the "Find" feature (control+F);
- View the navigation pane within your PDF viewer ("side bar," "bookmarks bar," or "drawer");
- Click on section headers within the navigation pane, scroll through pages, use up and down arrows; *or*
- Reference the Site Map for a linked outline of all help content.

Algebra & Functions	Geometry & Trigonometry	Statistics & Probability
CAS *Graphs & Tables* *Symbolic Manipulation*	**Synthetic**  *Draw & Measure* *Construct & Transform*	**Data Analysis** *Graphical Display* *Statistical Analysis*
Spreadsheet *Formulas* *Data Sort*	**Coordinate**  *Program & Animate* *Geometry Commands*	**Simulation** *Build & Run* *View & Analyze*
Custom Apps 	*Custom Apps* 	*Custom Apps*

Quick Links

Catalog	Index	Save & Print	Advanced Apps

Core Math Tools

www.nctm.org/coremathtools

Core Math Tools is a suite of Algebra & Functions, Geometry & Trigonometry, and Statistics & Probability software tools designed to support implementation of the Common Core State Standards for Mathematics.

Core Math Tools includes three families of software:

- ***Algebra & Functions***—The software for work on algebra problems includes an electronic spreadsheet and a computer algebra system (CAS) that produces tables and graphs of functions, manipulates algebraic expressions, and solves equations and inequalities.
- ***Geometry & Trigonometry***—The software for work on geometry problems includes an interactive drawing program for constructing, measuring, and manipulating geometric figures and a set of custom apps for exploring properties of two- and three-dimensional figures.
- ***Statistics & Probability***—The software for work on data analysis and probability problems provides tools for graphic display and analysis of data, simulation of probabilistic situations, and mathematical modeling of quantitative relationships.

This suite of tools is built upon several open source projects. See the *Core Math Tools* license information.

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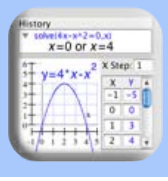
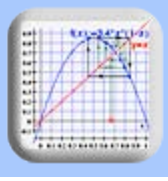
Help Site Map:

- Help Topics at Glance

- Core Math Tools Help
  - Algebra & Functions
    - CAS
    - Spreadsheet
    - Custom Apps
    - Index
    - Commands
  - Geometry & Trigonometry
    - Interactive Geometry
    - Custom Apps
    - Index
    - Commands
  - Statistics & Probability
    - Data Analysis
    - Simulation
    - Custom Apps
    - Index
- Advanced Apps
- Save & Print
- Data Sets
- Catalog
- Index
- License Information
- General Public License

Algebra & Functions

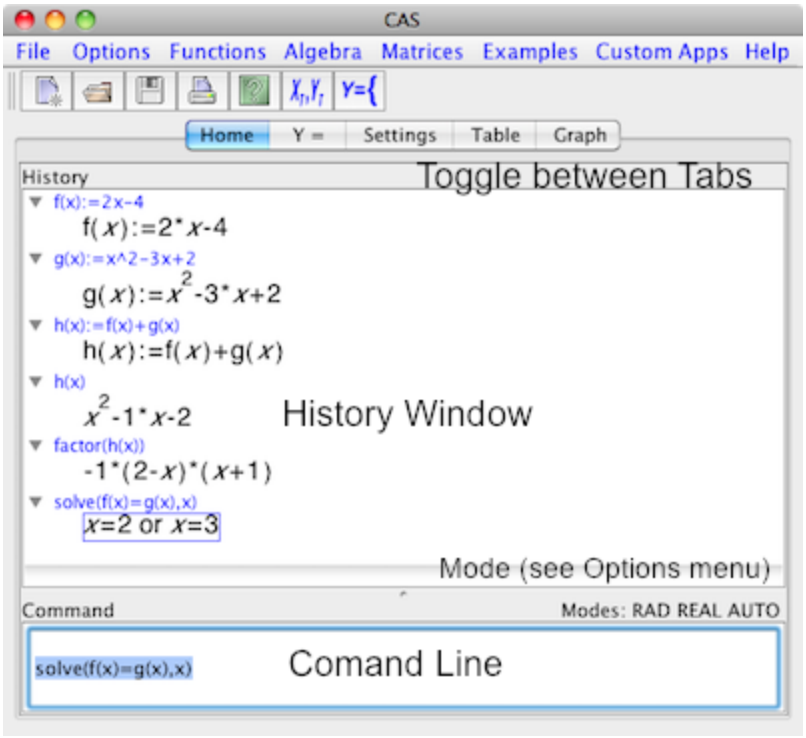
Algebra and Functions tools include a Computer Algebra System (CAS) and a Spreadsheet. With the CAS: produce tables and graphs of functions, manipulate symbolic expressions, and solve equations and inequalities. With the Spreadsheet: use familiar spreadsheet formulas and insert data from other sources.

CAS	Command Line	Graphs & Tables	Custom Apps
			
Manipulate expressions and equations, display and transform graphs and tables.	Execute commands for symbolic algebra, compute, and define objects for later use.	View graphs and tables of defined 2D or 3D functions and equations.	Explore function iteration and linear programming in user-friendly environments.
Spreadsheet	**Formulas**	**Edit Options**	**Sort, Graph, Analyze**
Display and compute data stored in a grid, and relate rows and columns by formulas.	Relate cells and columns of a spreadsheet with user-defined formulas.	Customize rows and columns, cut, copy, paste and insert, set digits and align.	Use tools for analysis of data including sort, graph, and Chi-Square Test.
Index	**Catalog**	**CAS / Spreadsheet**	**Save & Print**
Browse help topics specific to Algebra & Functions in A-Z order.	Listing of available commands with examples for Algebra & Functions.	Modify settings and stylistic attributes of created objects.	Core Math Tools (CMT), Image (GIF) and Text (TXT) files are file types.

See also Help Topics at a Glance or Go Online for Additional Resources.

CAS

A computer algebra system or CAS is a representational toolkit that allows one to manipulate symbolic expressions and equations, to compute results in approximate and exact forms, and to create, move between, and transform linked graphic and numeric representations of functions.



Tools

- The Home tab (shown at left) can be used to define, calculate, and manipulate numerical and algebraic expressions and equations through commands.
- The Y= tab is used to define explicit or implicit functions (equations) to be manipulated or represented as tables or graphs.
- The Settings tab becomes available when at least one equation has been defined and selected in the Y= menu.
- The Table and Graph tabs display representations of all defined and selected equations specified in the Y= tab.
- The Data tab is accessible by choosing File | Data in the Home tab.

Home

Type into the Command line and press Enter to execute a command. Each entry will be recorded above in the History. Click on a result in the History and press Enter to re-enter it into the Command line.

> Note: Some equations defined as explicit or implicit functions in the Command line (e.g., those involving function notation, or the variables x and y among others) will also be recorded in the Y= menu.
>
> See also Algebra & Functions Commands.

Symbolic Manipulation

The Algebra and Functions menus, and Options | Math Toolbar entries from the Home tab give common commands to use for CAS. Click here for explanations and examples of these commands in use.

Type +, -, *, /, ^ to substitute the last expression into an additional expression in the Command line.

> Example. Keystrokes used in Command line: 3x+11=5x+7 [Enter] -3x [Enter] -7 [Enter] /2 [Enter].
> Recorded in History: 3*x+11=5*x+7; 11=2*x+7; 4=2*x; 2=x.

A common error displayed in the History is "Syntax error," which indicates that the symbols used in the

previously entered command may be out of order, missing, or inappropriately used. Check for correct spelling and use of parentheses.

Settings

Setting the mode and default display of computations is done using the Home | Options menu.

> See also Settings for Graphs and Tables.

- The default Mode is Radian. Choose Options | Degree Mode to compute in degrees instead.

  > Note: The mode must be set in the Home tab; this setting applies to the entire CAS (Home, Y=, Settings, Table and Graphs).

- Select Options | Complex Numbers to compute in this field (the default is Real numbers). This entry must be selected for `i` to be defined as the square root of negative one.
- Choose Options | Set # of Digits to determine the numerical display of computed expressions. Choose from 0, 1, 2, 3, 4, 5, 6 or All (the default is 4).
- By default, results are automatically simplified (Options | Auto Simplify).
- To show approximations of numeric computations, select Options | Auto Numeric.

  > For example, in Auto Numeric mode type `2/3` to yield `.6667`. Otherwise, `2/3` will be displayed.
  >
  > Note: Another way to express numeric expressions in decimal form is to contaminate an expression with a period ".". For example, compare the results of expressions `(4./5)^2` (a period after the 4) and `(4/5)^2` (no period).

Matrices

Use the Home tab Matrices menu to define new matrices, edit existing matrices, perform matrix computations, and view matrices as vertex-edge graphs.

There are several ways to define new matrices:

- Choose Matrices | New Matrix and follow the prompts:
  1. Give the matrix a simple name (e.g., a single character "m" or short word(s) without spaces).
  2. Type a numeric value for the number of rows, a comma, and a numeric value for the number of columns (e.g., 2,3 for a 2x3 matrix).
  3. Type the values for each cell of the matrix then choose Matrix | Save to record the matrix in the history.
- Type into the Command line with the following syntax:

  ```
  matrixName:=[[column 1],[column 2],...[column n]]
  ```

  where `[column 1]` is a list of the entries of the first column in the form `[a11, a21, ..., an1]` such that `a11` is the first entry of the first column, `a21` is the second entry of the first column, and so on.

- Select an entry of the Examples menu or Sample Matrices. For instance:

`m:=matrix(2,3)`	Let the character `m` reference a 2x3 zero matrix. Type `m` Enter in the Command line to call this matrix.
`m:=matrix(2,2,a,b,c,d)`	Let the character `m` reference a 2x2 matrix with row entries a, b, and c, d. Type `m` Enter in the Command line to call this matrix.
`m:=[[1,2],[3,4]]`	Let the character `m` reference a 2x2 matrix that is defined by its first and second columns: [1,2] and [3,4]. Note: Be sure to include a comma (",") between the two column matrices.

To edit a matrix:

- Choose Matrices | Matrix Editor. Select a matrix to Edit. Type into the Matrix Editor window then Save when finished.

Note: The Matrix Editor | Edit menu offers options to Add Row, Add Column Delete Row, and Delete Column. Click in the desired cell then choose an Edit menu option.

- Click on a matrix in the Home | History to box it, press Enter. Edit the matrix values within the Command line, press Enter when finished.

To compute with matrices type into the Command line or use the Matrix | Functions menu. Click below to view an explanation of a command and see examples of its use:

`matrix()`, `inv()`, `det()`, `id()`, `tr()`, `size()`, `row()`, `col()`.

View a matrix as a Directed or Undirected Vertex Edge Graph by choosing the desired entry from Home | Matrices | View Matrix As. The selected matrix will be treated as an adjacency matrix and will be represented as a vertex-edge graph in a new window.

See also Advanced Apps | Vertex-Edge Graphs.

Y=

The Y= tab is used to define, select, and edit equations and functions that can later be viewed in the Table or Graph tabs.

Define Equations and Functions

In general, any explicit or implicit equality or inequality that relates variables is an allowable function that may be defined in either the Y= tab or the Home tab. Some Help Tips are included below:

- Parametric functions, piecewise functions, and three-dimensional curves can also be defined; examples of each are given in the Y= tab Examples menu.

  See also Algebra and Functions Commands, Matrices.

- To define f(x) as a function, `f(x):=` is the appropriate syntax.
- Use dependent variables that are distinct when you want to view a simultaneous table of values. For example, `y1=x+2` and `y2=-2x-3`.
- In an explicit or implicit expression relating variables, the letter closest to z is treated as the dependent variable (i.e. plotted on the vertical axis, commonly the y-axis).
- A list of defined functions can be saved as a text file to use later.

  See also Save & Print.

Select and Edit Equations and Functions

Type into the Y= Command line end press Enter; it will be listed below. Options to box and select equations/functions include:

- Box an equation by clicking on it to edit or delete it.

  Press Enter to re-execute a boxed equation in the Command line to edit it (or choose Edit | Edit Boxed Equation). Choose Edit | Delete Boxed equation to remove it from the Y= list.

  Choose Edit | Clear All to erase all currently defined equations listed in the Y= tab.

- Select an equation by clicking the check box to the left of it to view it's Settings, Graph, and Table.

  If there is no check mark to its left, the equation is not selected and the settings, graph, and table cannot be viewed.

  Choose Edit | Select All or (Edit | Deselect All) to check (or uncheck) all listed equations/functions at once.

Settings and Plot Options

When an equation has been defined, a pull down options menu becomes available to its left. Use this menu to select from Rectangular, Polar, Parametric, or 3D plot options.

> See also Home | Settings, Settings tab.

- Choose Rectangular for the standard Cartesian plane with horizontal and vertical axes representing the independent and dependent variables, respectively.
- Choose Polar for a polar grid which plots the radial distance from the origin and the polar angle.
- When a parametric function has been defined (of the form XY=[x(t),y(t)]) the Parametric option will automatically be checked. Otherwise, this option will remain unchecked.
- Choose 3D to accept an implicitly defined or explicitly defined function in three or fewer variables as defining a 3D curve. This option is useful when an equation such as x^2+y^2=2 is intended to represent a cylinder (3D mode) instead of a circle (2D mode). If the 3D option is not selected, implicitly and explicitly defined functions will be interpreted as representing 2D curves or lines.

Settings

The Settings tab allows you to modify the window options and plot styles that pertain to the Graph tab and Table tab. The Settings tab applies to all functions defined and selected in the Y= tab. Available options depend upon whether a function is 2D (explicit or implicit) or 3D.

> Note: A check mark must be next to at least one equation/function within the Y= tab for the Settings tab to be available.
>
> See also Home tab Settings.

Options

Quickly modify settings for graphs and tables with the Options menu.

- Choose Options | Standard Window ( ) to change the graph window to the standard view: domain=(-10, 10) and range=(-10, 10).
- Choose Options | Trig Window ( ) to change the graph window to the standard trigonometric view. In Degree mode: domain=(-360, 360) and range=(-3, 3). In Radian mode: domain=(-2pi, 2pi) and range=(-3, 3).

  > Note: The Mode (Degree/Radian) should be set prior to executing trigonometric commands and adjusting settings.
  >
  > See also Home tab Settings.

- When Options | Simultaneous is checked settings will be grouped. Otherwise they will be separated by tabs.

2D Functions

The 2D Functions tab within the Settings tab pertains to all selected functions that are defined explicitly from within the Y= tab (e.g., the dependent variable is written as a function of the independent variable such as y=x+2).

> Note: If Options | Simultaneous is *not* checked, then each explicitly defined function will have its own sub tab to adjust settings individually.

- Plot Style can be set to: Points Only (at Delta X step interval), Line/Curve, and Points with Connections.
- Minimum and Maximum X and Y: Type values and press Enter to set the lowest and highest bounds for the horizontal (independent, x-) and vertical (dependent, y-) axes on the Graph and

starting value for the Table.
- Set Delta X (or change in x, the independent variable) to determine the plot display and grid lines for the Graph and interview for the Table.
- Select Auto Scale (Fit) to define the graph window to fit the selected function.

The Implicit sub tab within the Settings tab pertains to all selected functions that are defined implicitly from within the Y= tab (e.g., `4x+y=8`). Minimum and maximum x and y values can be set for this type of 2D Function.

3D Plots

Settings for 3D Plots can be changed for each plot that is defined. Values for minimum and maximum X, Y, and Z coordinates can be changed for both the View Bounds and Graph Bounds.

- View Bounds:
  - Check Use Window Bounds so an appropriate viewing window is used automatically.
  - Check Show Axes and Bounding Box to display these graph features.
  - Check Show XYZ Orientation to show axes for clarity when rotating the plot.
  - Change the View from 3D to XY, XZ, or YZ if you are interested in seeing the two-dimensional plane view.
- Graph Bounds:
  - If multiple 3D plots are checked, choose the one you want to set Graph Bounds on from the Select Existing drop-down.
  - Adjust the appearance of each 3D plot including the minimum and maximum graph bounds for each axis.
  - The "discr" setting determines how fine-grained the graphical view will be within the minimum and maximum values for X, Y, and Z.

    Note: When simultaneously graphing multiple 3D functions it may be helpful to make one of the plots Transparent and to Color By: Z to better view the intersection.

Tables

The Table tab becomes available once an explicitly defined 2D Function or a 3D Plot is selected within the Y= tab. The settings that were determined within the Settings tab apply to the Table tab. Some Help Tips are include below:

See also Settings | Options.

- If you are unable to view the contents of the Table tab, check the Y= tab. There must be a check mark next to an explicitly defined 2D Function or a 3D Plot.
- You can view the table of values for more than one 2D function at a time. In this case, it is helpful to define the functions using different function names.

  For example, using `y1(x):=8cos(x-30)+2` and `y2(x):=6sin(x-60)+3` will give `y1` and `y2` as headers in the table, helping to distinguish between the two.

- When viewing the table for a 3D plot, it is best to view them one at a time. Also, selecting any of the index check boxes at the left will highlight the corresponding grid point in the 3D plot.
- To view more values than displayed in the table for a 2D function, click on a table entry then use the up or down arrow key on the keyboard.

See also Save & Print.

Graphs

The Graph tab becomes available once a function is defined and selected within the Y= tab. The window

settings that are chosen from within the Settings tab determine the initial graphical display. Also use the Zoom and View Options to customize the display.

> Note: To trace (i.e., view the coordinates of points) a graph move the cursor over the graph.
>
> See also Save & Print.

Zoom Settings

Determine the Window in the Settings tab or use the Graph tab Zoom menu:

- Choose Zoom Box then drag a box around the desired section of the graph to zoom in on.
- Choose to Zoom In on the current plot to cut the window range in half.
- Choose to Zoom Out on the current plot to double the window range.
- Select Zoom Sqr to adjust the window range to be a square (relative to the window size).
- Choose Zoom Std to set the domain and range from -10 to 10, the Standard viewing window.
- Select Zoom Trig to set the domain to (-360,360) or (-2pi, 2pi) and the range to (-3,3), appropriate for trigonometric functions.

> Note: Set the mode in the Home | Options menu before adjusting the window or zoom settings.

Graph View Options

Options menu:

- Select Options | Split View with Table to show the Table to the right of the graph. Otherwise the graph is shown by itself.
- Choose to Show Equation, Draw Axes, and Draw Grid. When unchecked, the equation, axes, and grid are hidden.

> Note: Choose Options | Polar Grid to show (or hide) a polar grid. It may be useful to hide the (Cartesian) grid when this options is selected.

- For a 3D plot, choose Options | Shading to add shading to the curve/surface.
- Choose the button to show (or hide) parameter Sliders. Each parameter will have its own slider bar named according to how it was defined.

> Note: This option pertains to plotted functions that include parameters. For example, define and select y=a*x+b in the Y= tab. Notice the slider bars for a and b within the Graph tab.

  - Drag and release the slider to adjust the value of each parameter. Or, click on the name of a slider then type its value to adjust it.
  - When selected, Options | Sliders Snap to Mark allows parameter sliders to adjust at step intervals. Otherwise, sliders are prevented from snapping to marks.

Slice 3D Plots

The Slice menu of the Graph tab is only available when viewing 3D Plots. It allows you to position a slicing plane, parallel to either the x-y plane, y-z plane, or x-z plane, and examine how the slicing plane intersects the 3D plot(s).

- Check On in the Slice menu to enable a slicing plane in the 3D Plots display. Otherwise the slicing plane is hidden.
- Check Hide Surfaces in the Slice menu while On is checked to hide the 3D plot(s). This allows you to focus solely on the intersection of the slicing plane with the 3D plot(s) without those curves obscuring anything.
- Choose a slicing option--Slice X (, Y-Z Plane), Slice Y (, X-Z Plane), or Slice Z (, X-Y Plane)--to enable the view of a slicing plane. Drag the slider to move the slicing plane across the viewable window.

Data

To view a data tab, choose File | Data in the Home or Y= tab.

Help topics on Data sheets are available in the Data Analysis Help. Note however that Data tab functionality is slightly different than the Data Analysis tool:

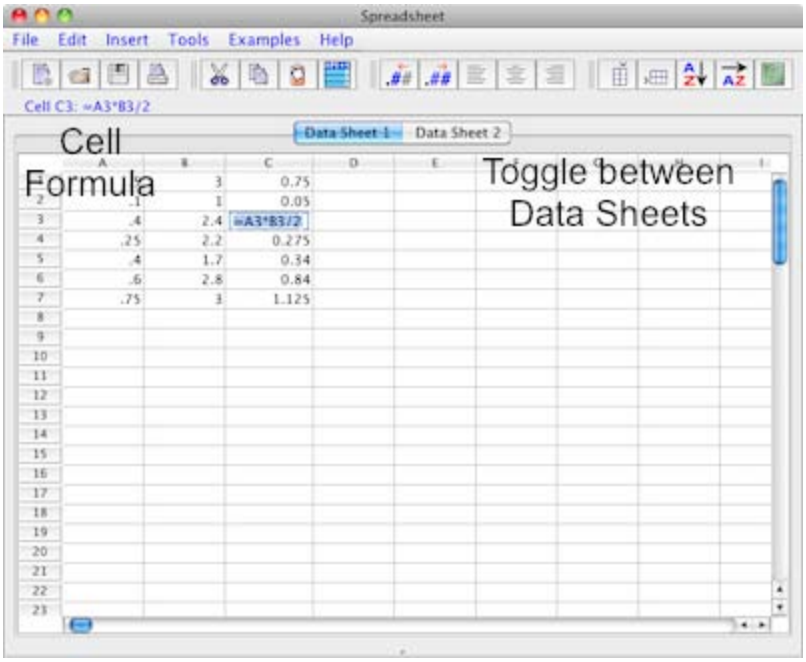
- Scatterplot ( ) is the only Graph menu option available within the Data tab. Access the Statistics Data Analysis tool to use other graph options such as Histogram and Box Plot.

  > Note: If you choose to plot a scatterplot from data within the Data tab of *CAS*, the scatterplot will be available within the Graph tab. Choose to plot functions over the scatterplot by selecting them in the Y= tab. Also plot multiple scatterplots in the same window by enabling more than one from within the Y= tab and adjusting the window Settings as needed.

- Summary Statistics and Custom Apps for Statistics are not available within the CAS Data tab. Access the Statistics Data Analysis tool instead.

Spreadsheet

A spreadsheet allows one to display and compute data stored in the cells of a grid, and relate rows and columns by formulas.



Basics

- Cells are referenced according to their location by column (vertical arrangement is alphabetized by letter) then row (horizontal arrangement is numbered).

  For example, the cell highlighted at left is "C3" (column C, row 3).

- Select a single cell by clicking on it. To select multiple cells at a time: (1) click and drag over a region with the mouse, (2) hold down the Shift key while you click, or (3) hold down the Control key while you click to select non-adjacent cells.

Formulas

Formulas in a spreadsheet allow cells to be related so that the entry of one cell can be calculated from a value or values in different cells.

See also Insert Function, Examples.

Getting Started

Some general tips on using formulas are listed below:

- To enter a formula, type an equals sign (=) and then the formula you wish to use. Press Enter.
- Single-click a cell to view the formula used to compute it. Double-click a cell to edit the formula.
- Cells can be used in calculations by referencing their cell name. Any cell referenced in a formula must contain a numerical value or the formula will produce an error. For example:

  =B1^2+5 If cell B1 has a value of 2, the cell containing this formula will get the value of the square of cell B1 plus 5 (i.e., 2^2+5=9).

- Place a dollar sign ($) in front of the column or row reference to fix the reference of that particular column or row. The row and/or column that is fixed will not change if that cell is copied and pasted or filled down a particular column. For example:

  =$B1^2+5 Fixes the column reference (column B) and allows the row reference (row 1, 2, 3, etc.) to vary.

=B$1^2+5 Fixes the row reference (row 1) and allows the column reference (column B, C, D, etc.) to vary.

=B1^2+5 Fixes both the column (column B) and row (row 1) references.

See also Examples.

Fill Down, Column Formula

Both the Fill Down and Column Formula entries of the Edit menu allow you to apply formulas to entire regions of cells at a time. This saves time in entering formulas.

- Choose Edit | Fill Down or to apply a given formula to the selected cells below it.

  See also Examples.

- Select a column (click in a cell of the desired column), then choose Edit | Column Formula. In a separate dialogue box, type the desired formula, then click OK (e.g., "=A1+2"). The entered formula will then be applied to the entire column that was selected.

  See also Getting Started.

Insert Function

Choose Insert | Function for a listing of common functions. Click on a function name below for a full description of its use:

See also Algebra & Functions Commands.

Basic Statistics	Trigonometric	Combinatorics	Other Functions
• sum() • average() • stdev() • count() • max()	• sin() • invsin() • cos() • invcos() • tan() • invtan()	• perm() • comb() • fact() • floor() • ceil()	• abs() • sqrt() • root() • log() • ln() • exp()

If inserted into an empty cell, simply type between the parentheses (i.e., "`=functionname()`"). If the selected cell is not empty, the function name will be inserted at the end of those contents. To be executed as a formula, you must use the equals sign "=" immediately preceding the function name.

Examples

Shown below are two examples of using the Fill Down option with formulas. Example 2 shows the use of fixed cell references.

Example 1. Using Fill Down with variable cell references.

	A
1	5
2	
3	
4	

Suppose that you have entered a value into a spreadsheet, as shown in cell A1 at right. Next, a formula will be used to relate each cell in column A to the cell above it.

	A
1	5
2	=A1+5
3	
4	

Type a formula into cell A2 so that its value is 5 more than the value in A1 (=A1+5). Then select cells A2 through A4.

	A
1	5
2	=A1+5
3	=A2+5
4	=A3+5

Choose Edit | Fill Down . The cells to the right display the formulas contained in each cell. NOTE: If a cell contains a formula, the numerical

	A
1	5
2	10
3	15
4	20

The numerical values corresponding to each of the formulas described above are shown here.

value of the formula is shown unless the individual cell is selected.

Example 2. Using Fill Down with fixed and variable cell references.

	A	B
1	5	
2	10	
3	15	
4	20	

Suppose you have data entered in column A. Next, a formula will be used to relate each cell in column B to a fixed cell and a variable cell in column A.

	A	B
1	5	=A$1^2+A1
2	10	
3	15	
4	20	

Enter a formula into cell B1 so that its value is the square of cell A1 plus the corresponding column A cell value. Then select cells B1 through B4.

	A	B
1	5	=A$1^2+A1
2	10	=A$1^2+A2
3	15	=A$1^2+A3
4	20	=A$1^2+A4

Choose Edit | Fill Down to obtain the desired formulas in cells B2 through B4, as shown to the right. Notice the fixed and variable references used.

	A	B
1	5	30.0
2	10	35.0
3	15	40.0
4	20	45.0

The numerical values corresponding to each of the formulas as described above are shown here.

Edit and Insert Options

The Edit and Insert menus offer functionality to move and shift cells, delete and insert rows and columns, and to modify settings and styles of spreadsheet cells.

Move and Shift Cells

Use the Edit menu, toolbar icons, or keyboard shortcuts for quick cut, copy, and paste options for selected regions of cells. Also shift cells or regions of cells at a time.

> See also Delete Column(s)/Row(s) and Insert Column(s)/Row(s).

- From the Edit menu, choose to Cut or Copy (control+C) selected cells and temporarily store them on the clipboard.

  > Note: The temporary storage will be replaced when anything else is cut or copied.

- Choose Edit | Paste (control+V) to view the cut or copied cells on the clipboard. Be sure to click on the the top-left cell of the rectangular region to be pasted into before pasting.
- Choose Insert | Shift Cells Right/Down to move the cell or selected region of cells accordingly.

  > Note: Any cells that were to the right of/below the selected cells also get shifted to the right/down to make room for the selected cells. Cell formulas are updated where necessary as cells move.

Delete and Insert Row(s)/Column(s)

Use these options to remove and shift entire row(s) and column(s) of a spreadsheet at a time:

- Choose Edit | Delete Row(s)/Column(s) to remove the selected row(s)/columns(s) from your spreadsheet. Any contents that were below/to the right of the deleted selection remain.

  > Note: This action cannot be reversed.
  >
  > See also Cut, Copy, Paste.

- Choose Insert | Row(s) to add a row above the selected cell. Choose Insert | Column(s) to add a column to the left of the selected cell.

  > See also Shift Cells right or down.

Settings and Styles

Customize the display of cells including the vertical alignment, the number of digits displayed (including increase and decrease by one), and the mode. Also choose to edit the column name from the default alphabetical name.

> See also Sort data.

- Choose Edit | Align to specify the horizontal position of text within a selected column. The alignment options are Left ( ), Center ( ), and Right ( ).
- Choose Edit | Set # of digits to determine the number of decimals that are displayed for any data entry that is in formula format (e.g., `=0.14`) in the selected column(s). You may choose to show 0, 1, 2, 3, 4, 5, 6, or All decimal values (the default setting is 6). Alternatively, select the desired column(s) then choose .## (or .##) to decrease (or increase) the number of digits (decimal places) by by one.

  > Note: When you manually type a number in a cell that is not a formula it is assumed that the desired # of digits (decimal places) is already set. The Set Digits options only apply to formulas.

- Choose Edit | Column Name then type the desired name into the "Edit Column Name" box. Click OK to change the name from the default naming.

  > Note: If a column is renamed, you may use the new column name within a formula (as long as the first characters in the name are not numerical) by typing the first characters of the name until the first space. For example, suppose column A is renamed to "Test." In column B type `=A1*3` OR `=Test1*3`.

- Choose Edit | Degrees or Edit | Radians to set the mode of displayed computations in degrees or radians, respectively. The default setting is Degrees.

Tools

Most tools available in spreadsheet are also available within the Statistics | Data Analysis tool. Options to Sort, Graph, or view Summary Statistics are explained below.

Sort

The two Tool menu options for sorting data are Sort All Rows by and Sort All Columns by. Two different methods for using these features are suggested below:

1. Sort groups of rows/columns at a time.
   - Without cells selected, choose a sorting option (,).
   - "In": Control+Click the desired rows/columns to group together and include in the sorting.
   - "By": Control+Click the desired rows/columns to determine the sorting (the selected row/column listed first will determine the primary sorting). Click OK.

     > Note: This method is desirable if the spreadsheet cells are related to one other (e.g., bivariate data with pairings by rows).

2. Sort select rows/columns individually.
   - Select the desired rows/columns to sort. Control+Click to select non-adjacent cells
   - Choose the desired sorting option (,). Only the selected cells will be sorted, all other cells will remain unsorted.

     > Note: This method is *not* desirable if the spreadsheet cells are related to one other (e.g., bivariate data that include specific pairings).

Graph

Spreadsheet graph options are organized by type below. The links on each graph type redirect to additional help topics within Data Analysis (or Advanced Apps for Contour plots):

Univariate	Bivariate	Statistical	Multivariate
• Histogram • Box Plot	• Scatterplot • Matrix Plot	• Times Series • Normal Plot	• Contour / 3D Plot
Use a single column, or Control+Click to select more than one column of data for a "stacked" graph.	Two (or more) columns must be selected. Scatterplots require one independent and one dependent column.	May involve more than one column of data (multi-column graphs will be color-coded).	Uses the number of rows and columns to determine the size of the grid and the entries of these cells as the "height" of the contour plot.

Summary Statistics

Choose Tools | Summary Statistics to compute Descriptive statistics (n, mean, minimum, q1, median, q3, maximum, sample standard deviation, and sample variance) and analyze Regression based on a selected model (linear, quadratic, cubic, quartic, power, exponential, logarithmic, polynomial, sinusoidal).

> Note: For Regression analysis first choose the independent and dependent variables, then click OK. A separate Regression Analysis Frame will appear with Results, Graph, and Residuals in tabs across the top.
>
> See also Statistics & Probability for additional help topics.

Data

Choose a data set from the Data menu for quick access to pre-loaded data examples.

> See also Data Sets for more information.

Algebra & Functions Custom Apps

The Custom Apps for Algebra & Functions focus on graphical representations of functions. A description and help topics for each of these tools is given below:

Function Iteration
Linear Programming

Function Iteration

Illustrate the graphical iteration process for functions.

Instructions:

1. *Determine the function*
   There are multiple ways to determine the desired function to be used with this tool: (1) drag the *a* and *b* sliders (or click the buttons) to vary the parameters for the linear function f(x)=a*x+b; (2) type into the text box to the right of "f(x)=" to replace the given expression with one of your choosing; (3) select an entry from the Examples menu; (4) choose Now-Next from from the Iteration menu for an alternative form for determining the function.
2. *Set the initial value*
   Type an *Initial Value* into the text box just above the table and press Enter. Equivalently, drag the red point along the x-axis to adjust the initial value dynamically.
3. *Control the iteration speed and window view*
   The Controls menu entries and their corresponding toolbar buttons allow you to start (▶), pause (❚❚), reset (|◀), and determine the speed (▶▶) at which the iterations are performed. Utilize features of the Iteration menu, View menu, and Options menu to customize the way the graphical iteration process is performed and is viewed.
4. *View time series plot*
   Choose the Time button to view a time series plot of the number of iterations versus the evaluated function values. Click this button a second time to toggle back to the web view.
5. *Save or print screen*
   Use the entries of the File menu and its corresponding buttons to save (💾) or print (🖶) the current screen. Files are saved as images so the ".gif" filename extension is appropriate when saving and naming files.

See also Save & Print.

Iteration menu

- Choose Iteration | Show Fixed Points (✓) to highlight fixed points (if any) and display their value below the graph. Select this option again to hide any fixed points.
- Select Iteration | Show Web (✓) to show (or hide) the web created through the iteration process.
- Select Iteration | Time Series (Time) to toggle between the graph of the function and a time series

plot of the number of iterations versus the function value at each iteration. Notice that the initial value can be adjusted from the Time Series view by dragging the red dot vertically or typing a value to change it manually.
- Choose Iteration | NOW-NEXT or Iteration | Function to determine the form of the functions that are entered. The "NEXT=" form should involve the NOW value. The function form uses "f(x)=" notation with variable x.

Controls menu

Use the Controls menu to to start, pause, reset, and determine the speed at which iterations are performed.

- Choose Controls | Go ( ) and Controls | Pause ( ) to start and stop the iteration at the specified speed.

  Note: The default speed is set to Fastest, which shows the iteration process almost automatically. At the Slow speed, each step of the iteration can be seen visually on the screen (with green arrows shown moving vertically to the function value then horizontally to the line y=x) and blue squares plotted along the function itself. Also notice the table values update as iterations are performed.

- To set the speed of the iteration process choose Controls | Step, Slow, Medium, Fast, or Fastest. Alternatively, the simulation will run one pace faster with each click of the button.

  Help Tip: If the speed is set at a Step pace, click the Go button to perform the next step of the iteration.

- Choose the Controls | Reset ( ) to clear all performed iterations on the graph and in the table

  Help Tip: If you vary the parameters of an expression after some iterations have been performed, those same iterations will automatically adjust with the new changes. To start fresh, first clear the iterations before changing parameter values of the function.

View menu

- Choose View | Window Settings to show (or hide) the settings screen. Type values for Minimum X, Maximum X, Minimum Y, and Maximum Y. Select the "Auto Fit" button to adjust the window size automatically. Alternatively, use the Zoom menu to utilize various zoom options.
- Entries of the Zoom menu and their corresponding toolbar buttons include Zoom Box ( ), Zoom In ( ), Zoom Out ( ), Zoom Sqr ( ), Zoom Std ( ), Zoom Trig ( ).
- Choose View | Set # of digits to set the number of decimals that are displayed for function parameters and table values. You may choose to show 0, 1, 2, 3, 4, 5, 6, or All decimal values (the default setting is 6).

Options menu

- When Split View with Table is checked in the Options menu, the Table of values are shown to the right of the graphical display. When unchecked, the table is no longer visible.
- When Options | Show Equation is selected, the equation of the function is displayed on the graph. Otherwise, the equation is not shown on the graph (yet is still visible above it).
- Choose Options | Draw Axes or Options | Draw Grid/Mesh to show or hide the axes and grid, respectively.
- Select Options | Sliders Snap to Mark and the parameter sliders snap to step intervals when dragged.

  Note: This option pertains to plotted functions that include parameters.

  Choose the button to show (or hide) the parameter Sliders. Each parameter will have its own slider bar. Drag and release the slider to adjust the value of each parameter. Click on the name of the parameter to adjust its value manually.

Linear Programming

Analyze an optimization situation by using constraint inequalities and an objective function to find the minimum/maximum. Both two-dimensional (2D) and three-dimensional (3D) linear programming problems can be examined.

The help topics below describe how to build a linear programming situation, how to analyze that situation, and how modifying the view can help bring forth features of the situation.

Build a Linear Programming Situation

- Choose to Clear All the current drawing(s) and remove any constraint inequalities and objective function that may be present. Alternatively, choose Tools | New to do the same.
- Enter a constraint inequality in the box next to the Constraint Inequalities checkbox. Use >= for greater than or equal to and <= for less than or equal to. For a 2D problem, the default variables used for function *f* are *x* and *y*; for a 3D problem, the defaults are *x*, *y*, and *z*. Repeat as needed until all constraint inequalities have been entered by first clicking the + button to add each new constraint inequality.

  Change the Variables: If desired, you can change the letters used to denote the function and/or any of the variables. Be sure to first choose whether this will be a 2D or 3D problem by checking or unchecking View | 3D. Select the Settings tab and rename the function/variables, making sure to hit Enter or Tab after you change an entry.

- Enter the Objective Function as an expression (note that the left-hand side of the equation is already provided).

Analyze the Situation

What is your purpose? Maybe you want to analyze the linear programming situation one constraint inequality at a time, resulting in the determination of the feasible region, and finalizing by using the objective function to find the minimum/maximum. Or perhaps you want to skip all the details and get right to analyzing the feasible region. Your intent determines the way you use this tool.

- View the region covered by a constraint inequality by clicking the checkbox next to that inequality. The window settings for the display automatically adjust to accommodate the new graph. Continue to click checkboxes to show all constraint inequalities graphed simultaneously (presumably showing a region of overlap, the feasible region).

  Show Only Positive Values: Typically for a linear programming situation, you are only interested in considering positive values. Thus, the default setting in the Constraints menu is to do just that, Show Only Positive Values.

- View only the boundary values of the region covered by a constraint inequality by selecting Constraints | Show Only Boundary.
- View the feasible region by selecting Constraints | Show Feasible Region or by clicking the button.
- Choose the or buttons to change the axis of rotation to the y- or z-axis, respectively.

Tool menu

The Tool menu offers options to Restart, Print, and Close the custom app.

- Choose Tools | Restart to give the original starting view, settings, and graph.
- Choose Tools | Print to print the currently selected frame.

  See also Save & Print.

Options menu

The Options menu allows you to modify the display of the 3D surface of revolution.

- Choose Options | Show Edges to toggle the wireframe of the surface of revolution.
- Choose Options | Show Surface to toggle the quadrilateral faces that comprise the surface of revolution.
- Choose Options | Show Meridian to toggle the 2D curve used to sweep out the surface of revolution.
- Select Options | Show 3D Axes to toggle the x-y-z coordinate axes.
- Choose Options | Rotate about Horizontal Axis ( ) to perform the revolution about the y-axis rather than the z-axis. Alternatively, choose Options | Rotate about Vertical Axis ( ) to perform the revolution about the z-axis rather than the y-axis.

Algebra & Functions Index

All help topics and commands that are available within the Algebra & Functions tools are listed below in alphabetical order.

2D Functions
3D Plots, Bounds
3D Plot Option (CAS)
3D Plot (Spreadsheet)
abs()
ans(1)
Adjacency Matrix
Advanced Apps
Algebra & Functions Commands
Alignment
Approximate
Auto Numeric
Auto Scale
Auto Simplify
average()
Basic Statistics Functions
binomcdf()
binompdf()
Box Plot
CAS
ceil()
Cell
Cell Reference
Center Align
chisqcdf()
chisqpdf()
Clear All (Y=)
col()
Column Formula
Column Name
comb()
Combinatorics Functions
Commands
Command line
complex()
Complex Numbers
conj()
Contour
Copy
cos()
count()
Custom Apps
Cut
Data (CAS)
Data (Spreadsheet)
Data Sets
Define Equation
Degree Mode (CAS)
Degree Mode (Spreadsheet)
Delete Equation
Delete Row, Delete Columns
Delta X
der()
Deselect All
det()
Directed Vertex Edge Graph
Draw Axes
Draw Grid
Edit Cells
Edit Equation
Edit Formula
Examples
exp()
expand()
fact()
Fcdf()
Fpdf()
Fixed Cell Reference
Fill Down
floor()
Formulas
Function Iteration
Graph (CAS)
Graph (Spreadsheet)
Hide Surfaces
Histogram
Home tab
i
id()
imag()
Implicit
Insert Cells
Insert Function
int()
inv()
invcos()
invNorm()
invsin()
invT()
invtan()
Left Align
Linear Programming
ln()
log()
Math Toolbar
Matrices
matrix()
Matrix Editor
Matrix Functions
Matrix Example
Matrix Plot
max()
Maximum
Maximum X, Y
Mean
Median
Minimum
Minimum X, Y
Mode (CAS)
Mode (Spreadsheet)
Move and Shift Cells
N
New Matrix
Normal Plot
normalcdf()
normalpdf()
Options menu (Graph)
Options menu (Home)
Options menu (Settings)
Other Functions
Parameter
Parametric Plot Option
Paste
perm()
piecewise()
Plot Style
Polar Plot Option
Print
prod()
Q1
Q3
Radian Mode (CAS)
Radian Mode (Spreadsheet)
real()
regeq()

Rectangular Plot Option
Regression
Right Align
root()
row()
Sample Matrix
Sample Standard Deviation
Sample Variance
Save
Scatterplot (CAS)
Scatterplot (Spreadsheet)
Select Equation
Set # of Digits (CAS)
Set # of Digits (Spreadsheet)
Settings
Settings (Home)
Settings (Y=)
Shading
Shift Cells
Show Equation
simplify()
Simultaneous
sin()
size()
Slice 3D Plot
Slice X, Y, Z
Sliders, Snap to Mark
solve()
Sort
Split View with Table
Spreadsheet
Standard Window
sqr()
sqrt()
stdev()
sum()
Summary Statistics (CAS)
Summary Statistics (Spreadsheet)
Symbolic Manipulation
Syntax Error
Table
tan()
tcdf()
Time Series
tr()
tpdf()
Trig Window
Trigonometric Functions
Undirected Vertex Edge Graph
View Matrix As
View Options (Graph)
Y=
Zoom Box
Zoom In
Zoom Out
Zoom Settings
Zoom Sqr
Zoom Std
Zoom Trig

Algebra & Functions Commands

The templates, functions, commands, and operators available for evaluating math expressions within CAS (Home and Y= tabs) and Spreadsheet (and Data Analysis Data Sheets) are listed below in alphabetical order.

Alphabetical Listing of Available Commands

Items whose names are not alphabetical (such as +, !, and /) are listed at the end. In general, when interpreting the table below, note that:

1. All commands that begin with a '**command(**' must end with a '**)**' to ensure proper syntax; and
2. The mode (e.g., Degree/Radian) should be set prior to executing commands.

Command	Explanation	Example(s)
abs(*Expr***)**	The absolute value of an expression	**abs(-15)** returns **15** **y=abs(x)+5**
ans(1)	Return the result of the previous calculation	**sqrt(16)** returns **4.0** then **sqrt(ans(1))** returns **2.0**
average(*x1,x2,x3,...,xn***)** **average(***ColARow1:ColARowN***)**	Return the average of a list of data (x1, ..., xn, OR from Column A Row 1 to Column A Row N)	**average(1,2,3)** returns **2** **=average(A1:A25)** returns **70** with Apartment Temperatures data in Column A (rows 1 through 25) of a data sheet
binomcdf(*n,p,x***)**	The probability of the sum of the events up to x given n trials with an event probability of p	**binomcdf(5,.8,4)** returns **0.6723** with Auto Numeric On
binompdf(*n,p,x***)**	The probability of x given n trials with an event probability of p	**binompdf(5,.8,1)** returns **0.0064** with Auto Numeric On
ceil(*Expr***)**	Returns the smallest integer not less than the given expression	**ceil(2.3)** returns **3** **y=ceil(x)**
chisqcdf(*x,y,df***)**	The area between x and y based on the degrees of freedom df	**chisqcdf(0,1.145,5)** returns **0.05** with Auto Numeric On
chisqpdf(*x,df***)**	The area to the right of x based on the degrees of freedom df	**chisqpdf(1,5)** returns **0.0807** with Auto Numeric On
col(*Matrix,n***)**	Show the nth column of a given matrix	**col([[1,2],[3,4]],1)** returns **[1,2]** **r:=[[4,8,1],[3,8,9],[4,7,9]]** **col(r,2)** returns **[3,8,9]**, the 2nd column of matrix **r**
comb(*n,k***)**	Compute the number of different combinations of *k* objects taken from *n*	**comb(5,2)** returns **10**

	objects	
complex(*a*,*b***)**	When in Complex Numbers mode, take an ordered pair of real numbers, (*a*, *b*), and return a complex number, *a* + *bi*	**complex(-5,7)** returns **-5+7*i***
conj(*Expr***)**	Compute the complex conjugate of the given expression	**conj(4+i)** returns **4-i**
cos(*Expr***)**	Evaluate the cosine of the given expression	**cos(pi)** returns **-1** in Radian mode **y=cos(x/2)**
count(*x1*,*x2*,...,*xn***)** **count(***ColARow1:ColBRowN***)**	Gives the number of elements in a list of data	**count(1,2,3,4,5)** returns **5** **=count(B1:C22)** returns **44** within 100-meter Freestyle data sheet
der(*Expr*,*Var***)**	Evaluate the derivative of an expression with respect a variable	**der(x^2,x)** returns **2x** **y:=der(x^3+x^2+x,x)** returns **y:=3x^2+2x+1**
det(*Matrix***)**	Calculate the determinant of a given matrix	**det([[2,0],[4,2]])** returns **4** **t:=[[7,3],[2,1]]** **det(t)** returns **1**
exp(*Expr***)**	Gives the special number 'e' and can be used as a base in expressions for exponential functions	**ln(exp(x))** returns **x** **solve(exp(x)=20,x)** returns **x=ln(20)**
expand(*Expr***)**	Rewrites an expression in an equivalent form that does not contain parentheses	**expand((6-(45/3))^2)** returns **81** **expand((6*x^2)*(4*x+12))** returns **24*x^3+72*x^2**
fact(*n***)**	Compute the factorial of a natural number	**fact(5)** returns **120**; equivalent to 5*4*3*2*1
factor(*Expr***)**	Rewrites an expression in factored form, when possible	**factor(3*x^2+6*x-24)** returns **3*(x+-2)*(x+4)**
Fcdf(*x*,*y*,*dfNum*,*dfDenom***)**	The area between x and y given the degrees of freedom of the numerator and denominator	**Fcdf(0,2.1,25,20)** returns **0.9528** with Auto Numeric On
Fpdf(*x*,*dfNum*,*dfDenom***)**	The area to the right of x given the degrees of freedom of the numerator and denominator	**Fpdf(5,25,20)** returns **0.0004** with Auto Numeric On
floor(*Expr***)**	Returns the largest integer less than or equal to the given expression	**floor(6.7)** returns **6** **y=floor(x)**
i	Defined as sqrt(-1) with Complex Numbers on	**sqrt(-1)** returns **i**
id(*n***)**	Show the nxn identity matrix in matrix form	**id(3)** returns **[[1,0,0],[0,1,0],[0,0,1]]** in matrix form
imag(*Expr***)**	Returns the imaginary	**imag(6i+42)** returns **6i**

	part of a complex number	
int(*Expr*,*Var*,*lowBound*,*upBound***)**	Compute the definite integral of an expression from lower to upper bound values	**int(sin(x),x,pi,2*pi)** returns **1-cos(2*pi)** and **-2** in auto simplify mode
inv(*Matrix***)**	Calculate the inverse of a matrix	**inv([[2,2],[1,2]])** returns **[[1,-1],[-1/2,1]]** **n:=[[1,1],[1,0]]** **inv(n)** returns **[[0,1],[1,-1]]** in matrix form
invcos(*Expr***)**	The inverse cosine of an expression	**invcos(1.)** returns **0** **y=invcos(x+pi)**
invNorm(*percentile*,*xbar*,*s***)**	The value given the percentile rank with mean x-bar and standard deviation s	**invNorm(0.05,25,6)** returns **15.1309** with Auto Numeric On
invsin(*Expr***)**	The inverse sine of an expression	**invsin(1.)** returns **90** **y=invsin(2*x-pi)**
invT(*pvalue*,*df***)**	The t-value given a p-value and degrees of freedom df	**invT(.05,61)** returns **1.9996** with Auto Numeric On
invtan(*Expr***)**	The inverse tangent of an expression	**invtan(1)** returns **45** in Degree mode **y=invtan((x/2)*pi)**
ln(*Expr***)**	Take the natural log (base e) of an expression	**ln(exp(2))** returns **2** **y=ln(x)**
log(*Expr***)**	Take the log (base 10) of an expression	**log(100)** returns **2** **y=log(6*x)**
matrix(*r*,*c*,*Expr*,*Expr*,...*Expr***)**	Define a matrix with r rows, c columns, and its entries by row	**matrix(2,3,1,2,3,4,5,6)** is a 2x3 matrix with row entries 1,2,3 and 4,5,6 **m:=matrix(2,2,1,0,0,1)** then **m** returns the 2x2 identity matrix
[[col 1**],[**col 2**], ..., [**col k**]]**	Define a matrix by its column entries separated by commas	**[[2,3,0],[1,2,1]]** returns a 3x2 matrix with column entries 2,3,0 and 1,2,1 **k:=[[4,5],[7,9]]** then **k** returns a 2x2 matrix with row entries 4,7 and 5,9
max(*x1*,*x2*,...,*xn***)** **max(***ColARow1:ColBRowN***)**	Determine the greatest value in a list of data	**max(7,3,5,2,1)** returns **7** **=max(B1:C22)** returns **82.2** within 100-meter Freestyle data sheet
normalcdf(*x*,*y*,*xbar*,*s***)**	The area between x and y with mean x-bar and standard deviation s	**normalcdf(-infinity,19.2,25,6)** returns **0.1669** with Auto Numeric On
normalpdf(*x*,*xbar*,*s***)**	The area to the right of x with mean x-bar and standard deviation s	**normalpdf(5,25,6)** returns **0.0003** with Auto Numeric On
perm(n,k**)**	Compute the number of different permutations of *k* objects taken from *n* objects	**perm(5,2)** returns **20**
piecewise(*Expr*,*Expr*,...**)**	Create a piecewise function	**y=piecewise(cos(x),x<0,1.5^x,0<=x AND x<=4)** returns the two-part

		piecewise function on the specified domain
prod(*Expr*,*Expr*,...,*Expr***)**	Multiply a list of numerical values	**prod(5,4,3,2)** returns **120** **prod(2*x,x^2,x^3)** returns **2.0*x^6**
prod(*Expr*,*Var*,*Start*,*End***)**	Find the product of a variable expression for the specified variable for a range of numerical values from *Start* to *End*	**prod(3*x,x,1,4)** returns **1944** which equals (3*1)*(3*2)*(3*3)*(3*4)
real(*Expr***)**	Returns the real part of a complex number	**real(-3i+10)** returns **10**
regeq(1**)**	As long as a regression of some sort has already been performed on bivariate data, this will return the regression equation itself	**regeq(1)** returns **y=<the regression equation>** **y=regeq(x)** creates an equation in the **Y=** tab, but does not display the specific equation
root(*Expr*,*n***)**	Take the nth root of an expression	**root(27,3)** returns **3.0** **y=root(x,4)**
row(*Matrix*,*n***)**	Show the nth row of a given matrix	**row([[3,0],[0,5],[7,0]],1)**; returns first entries of each column, namely the row **[3,0,7]** **w:=[[2,2],[3,4],[5,1]]** then **row(w,2)** returns **[2,4,1]**
simplify(*Expr***)**	Rewrites an expression in an equivalent, simplified form	**simplify(6+10)** returns **16** **simplify((5x+3)*(2x+3))** returns **10*x^2+21*x+9**
sin(*Expr***)**	The sine of an expression	**sin(3*pi/2)** returns **-1.0** in Radian mode **y=sin(x+3)**
size(*Matrix***)**	Calculate the (row , column) size of a matrix	**size([[1,3,5],[7,9,11]])** returns **[3 2]** **n:=[[2,2],[4,4],[6,6]]** then **size(n)** returns **[2 3]**
solve(*Equation*,*Var***)**	Solve an equation or inequality for the specified variable	**solve(30=5*x^2+2*x+6,x)** returns **x=-12/5 or x=2**
sqr(*Expr***)**	The square of an expression	**sqr(17)** returns **289** **y=sqr(11*x)**
sqrt(*Expr***)**	The square root of an expression	**sqrt(225)** returns **15** **y=sqrt(36*x^2+1)**
stdev(*x1*,*x2*,...,*xn***)** **stdev(***ColARow1:ColBRowN***)**	Computes the standard deviation of a list of data	**stdev(1,2,3)** returns **1** **=stdev(A1:A25)** returns **2.16** within Apartment Temperatures data sheet
sum(*Expr*,*Expr*,...,*Expr***)**	Sum a list of numerical values or expressions	**sum(5,6,7,8)** returns **26.0** **sum(x,2x,-4x,17x,8x)** returns **24*x+0.0**
sum(*Expr*,*Var*,*Start*,*End***)**	Find the sum of a variable expression with respect to the variable for a range of numerical	**sum(x-4,x,1,4)** returns **-6**

	values from *Start* to *End*	
tan(*Expr***)**	Evaluate the tangent of an expression	**tan(45)** returns **1** in Degree mode **y=tan(pi/x)**
tcdf(*t1,t2,df***)**	The area between t1 and t2 based on the degrees of freedom df	**tcdf(-2,2,61)** returns **0.95** with Auto Numeric On
tpdf(*t,df***)**	The area to the right of t based on the degrees of freedom df	**tpdf(1,61)** returns **0.24** with Auto Numeric On
tr(*Matrix***)**	Transpose a given matrix	**tr([[1,2],[3,4]])** returns **[[1,3],[2,4]]** in matrix form **P:=[[1,1,1],[2,2,2],[3,3,3]]** then **tr(P)** returns **[[1,2,3],[1,2,3],[1,2,3]]** in matrix form
Expr **+** *Expr*	Add; Returns the sum of two expressions	**147+56** returns **203** **y=5*x+3**
Expr **at** *Var=Value* *Expr* **@** *Var=Value*	At; Evaluate the expression at the indicated value of the variable	**y=-x+3 at x=2** returns **y=1** **y=-x+3 @ x=2** returns **y=1**
Expr **/** *Expr*	Divide; Returns the quotient of two expressions	**-135/27.0** returns **-5.0** **y=1/x**
Expr **=** *Expr*	Equal to	**23^2=529** returns **true** evaluation **y=x**
Expr **>** *Expr*	Greater than	**16*24/3>129** returns **false** evaluation **y>2*x**
Expr **>=** *Expr*	Greater than or equal to	**47*13>=649** returns **false** evaluation **y>=6*x+4**
Expr **<** *Expr*	Less than	**23*13<300** returns **true** evaluation **y<10*x+2**
Expr **<=** *Expr*	Less than or equal to	**65*7<=490** returns **true** evaluation **y<=2*x-5**
Expr **%** *Expr*	Modulo	**27%12** returns **3**
Expr ***** *Expr*	Multiply, take the product of	**167*14** returns **2338** **y=6*x**
Expr **!=** *Expr*	Not equal to	**9/167!=0.1** returns **true** evaluation **y!=10+x**
Expr **^** *Expr*	Raise to the power of	**36^4** returns **1679616** **y=2^(x+1)**
Expr **-** *Expr*	Subtract; negative value	**64-13** returns **51** **y=3x^2-2x-1**

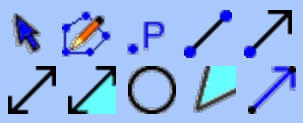
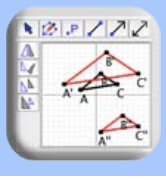
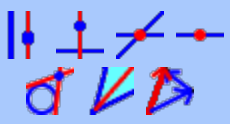
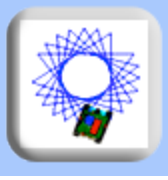
Math Toolbar

Choose Math Toolbar in the CAS Home tab Options menu to view the Typing Palette. From the typing palette, click on an available button to utilize it's functionality in the Command line.

Icon	Command	Icon	Command
	Expr **/** ***Expr***		**<**
	^2		**<=**
	sqrt()		**>=**
	root(*Expr***,***n***)**		**>**
	sum(*Expr***,***Var***,** ***Start***,***End***)**		**!=**
	prod(*Expr***,***Var***,***Start***,***End***)**		

Geometry & Trigonometry

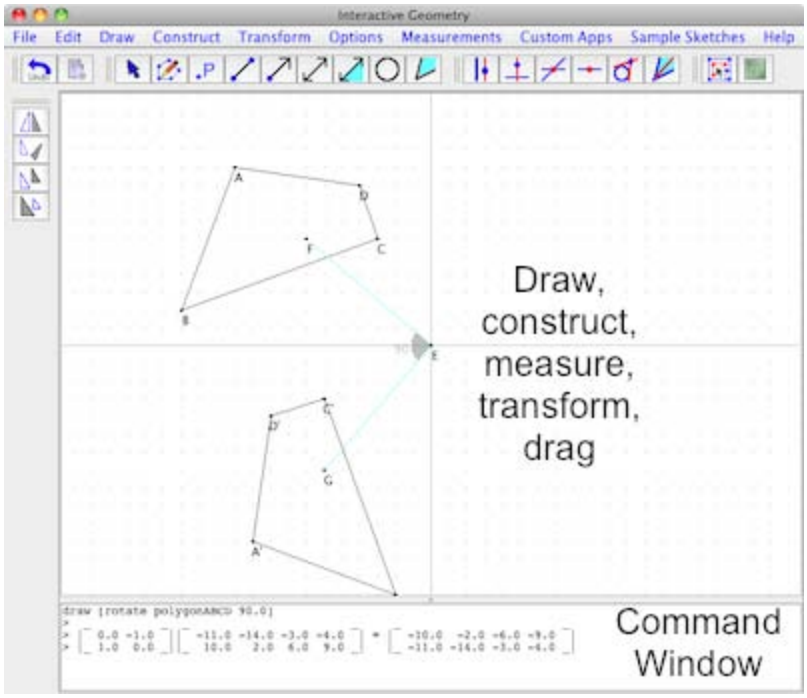
Geometry and Trigonometry tools include an interactive drawing tool for constructing, measuring, manipulating, and transforming geometric figures, a simple object-oriented programming language for creating animation effects, and a set of custom apps for studying geometric models in 2D and 3D. Interactive Geometry can be launched in a synthetic or coordinate environment.

Synthetic	Drawing	Measure & Calculate	Custom Apps
			
Explore the possibilities of dynamic geometry within a synthetic (non-coordinate) environment.	Click and drag to create and move objects with dynamic capabilities, select shapes to modify their properties.	Select an object and an attribute to be measured and use measurements in a Calculation.	Experiment with pre-designed sketches, animations, and dynamic figures, with support from on-screen prompts.
Coordinate	**Constructions**	**Transformations**	**Program & Animate**
			
Explore the possibilities of dynamic geometry within a coordinate environment.	Select an object(s) and a construction option for dynamic designs that always remain true.	Flip, turn, slide, and scale a drawn geometric object to a new location in the plane.	Execute a sequence of commands to define, draw, construct, and transform objects in the plane.
Index	**Commands**	**Settings**	**Save & Print**
Browse help topics specific to Geometry & Trigonometry in A-Z order.	Listing of available commands with examples for Interactive Geometry.	Modify stylistic attributes of created objects.	Core Math Tools (CMT), Image (GIF) and Text (TXT) are file types.

See also Help Topics at a Glance or Go Online for Additional Resources.

Interactive Geometry

Interactive Geometry is a dynamic geometry platform that allows one to construct, measure, manipulate, transform and animate geometric figures. There are three ways to use the features of tool: select an entry of the Menubar, click on a Toolbar icon, or type into the Command Window.



For example, three ways to Draw a Segment and Construct it's midpoint include:

1. choose Draw | Segment then Construct | Midpoint;
2. choose then ; or
3. choose Options | Command Window and type draw segment [[0,3][5,3]], draw midpoint [[0,3][5,3]].

The choice of Synthetic or Coordinate environments gives quick access to different pre-determined settings within this tool (e.g., grid axes off or on, respectively). Choose the desired environment from the main tools page

See also Settings.

Drawing Geometric Objects

Select the desired toolbar icon or its corresponding Draw menu option to activate a draw tool. Once a draw tool has been selected, the ability to draw that particular object will remain active until you select a different tool button or menu option.

See also Draw Commands, and the Measure and Calculate features.

Figure or Polygon		Click once for each vertex, then double-click to end.
Point	P	Click once to place a new point; place a point on a drawn object once highlighted.
Segment		Click and drag from first endpoint to second, or select two points.
Ray		Click and drag from first endpoint to second, or select two points.
Line		Click and drag from one point on the line to another, or select two points.
Half Plane		Click and drag from one point on the line of the half plane to another, or select two points.
Circle		Click and drag from center of circle to a point on the circle.

Angle	Click three times to define a point, vertex, and another point; angle is determined counterclockwise from initial to final.
Vector	Click and drag from initial point to second point, or select two points.

Selecting Objects

There are two common ways to Select drawn objects: use the tool (Shift click to select multiple), or choose Help | List of Shapes (Control click to select multiple, close the window).

Once selected, objects can be moved by dragging. The style of selected objects can also be changed.

> See also Transformations, Settings.

Measure and Calculate

To measure a drawn object, first select an object, then choose an attribute to be measured or calculated from the Measurements menu. Double-click a measurement to modify the Calculation, Label, and see the result within a Calculation window.

Each measurement option and the objects that can be measured using that command are listed below:

- Coordinates: Gives the matrix representation of any object drawn in the plane (defined by its points). Available within the Coordinate geometry environment only.

  > Note: All coordinate measurements will be represented by a matrix of size 2 x ? with the first and second rows for the x- and y-coordinates, respectively. Each column represents the coordinates of a single point. The Style of an object(s) can be changed to show coordinates as ordered pairs.

- Lengths: Gives the absolute value of the distance between points defining a segment, ray, line, half plane, circle, or angle.
- Angles: Gives the angle measure (in degrees) of an angle or all the angles in a figure or polygon.
- Slopes: Gives the slope of the segment, ray, line, half plane, or the segments defining a figure or polygon, or angle.
- Perimeter/Circumference: Gives the total distance around a figure or polygon, collection of segments, or circle.
- Area: Gives the total space enclosed by a figure or polygon, or circle.

Choose Measurements | Calculation to perform a calculation using numerical values, or previously-calculated results or measurements. Within a Calculation window:

1. Type the desired calculation (e.g., +, -, /, *); click on the drop-down list to insert an existing measurement or result.
2. Choose a label for the calculation (or leave it blank) and click the Test button (this is what will display on the screen).
3. Click OK to insert this labeled calculation into your drawing.

Constructions

Select an object(s) and a construction option from the toolbar or the Construct menu. Constructions remain true regardless of how the original object(s) are dragged.

> See also Construction Commands to program constructions within the Command Window.

Parallel		Both a straight line (segment, ray, or line) and a point must be drawn and selected to construct a parallel line.
Perpendicular		Both a straight line (segment, ray, or line) and a point must be drawn and selected to construct a perpendicular line.
Intersection		Draw and select two objects to construct their intersection (e.g., circle and line).
Midpoint		The midpoints of *all* selected segments, and all selected sides of figures or polygons will be constructed.
Tangents		Both a circle and a point (on or off the circle) must be drawn and selected to construct tangents.
Angle Bisector		Draw and select *one* angle to construct the angle bisector.
Add Vectors		Draw and select *two* vectors to add them.

Trouble-shooting Tips:

- Make sure the objects involved in the construction are the only objects selected. See also selecting objects.
- Constructions can be performed on polygons; you may need to draw a superimposed segment or angle first (the polygon is treated as one whole object, not as separate parts). See also drawing objects.

Transformations

Reflect (flip), Rotate (turn), Translate (slide), and Scale (stretch/shrink) a drawn geometric object to a new location in the plane. Options for using the Toolbar or Transform menu are explained below.

> Note: The Toolbar options (, , ,) are best for dynamic transformations determined by clicking and dragging. The "___ By" Transform menu options are best for a fixed transformation within the Coordinate environment.
>
> See also Transformation Commands to perform transformations within the Command Window.

Reflect

- Select a drawn object and the line of reflection then choose Reflect (). *OR*
- Deselect all objects then choose Reflect (). Click and drag from a drawn object for a dynamic reflection line. *OR*
- Select a drawn object then choose Reflect By. Type the coordinates of a point (separated by a comma) on the desired reflection line through the origin (this line cannot be changed once determined).

Rotate

- Select a drawn object and an angle by which to rotate then choose Rotate (). The angle determines the degree of the rotation in a counterclockwise direction about its vertex. *OR*
- Deselect all objects then choose Rotate (). Click and drag from a drawn object for a dynamic angle of rotation. The center of rotation may be inside the object or defined by a vertex (depending on where you click and drag from). *OR*
- Select a drawn object then choose Rotate By. Type the desired degree of the angle of rotation to rotate the object counterclockwise about the origin (this angle cannot be changed once determined).

Translate

- Select a drawn object and a segment then choose Translate (). The direction and magnitude of the translation is determined by the directed distance from the first toward the second point of the segment. *OR*
- Deselect all objects then choose Translate (). Click and drag from a drawn object

for a dynamic translation vector. *OR*

- Select a drawn object then choose Translate By. Type the desired x- and y-components of the translation (this is fixed and cannot be changed once determined).

Scale

- Select a drawn object and a segment then choose Scale ( ). The direction and magnitude of the scale transformation is determined by the directed distance from the first toward the second point of the segment. *OR*
- Deselect all objects then choose Scale ( ). Click and drag from a drawn object for a dynamic scale transformation determined by a directed segment. *OR*
- Select a drawn object then choose Scale By. Type the desired x- and y- components of the scale vector (this is fixed and cannot be changed once determined).

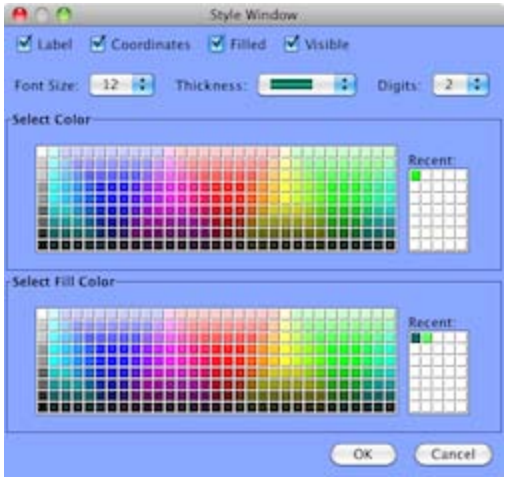
Settings

Use the Options and Edit menus to control the Settings. In general:

- use the Options menu to change the geometry environment settings for all created objects at once or *before* objects are created (e.g., choose Options | Default Settings, and the settings will apply to all *subsequently created* objects);
- use the Edit menu to modify stylistic aspects of selected objects *after* objects are created (e.g., select Edit | Change Style of Selected and the settings will apply to all *currently selected* objects).

A Style Window will appear after either of these options is selected (see illustration below).

See also Default Styles and Settings, Labels, Hide/Show or Delete Objects, and Undo.



Access the Style Window to adjust the following settings (Options | Default Settings OR Edit | Change Style of Selected):

- Label objects (default on) by capital alphabetical labels in the order they are created. See also Options | Hide Labels (hides all at once), and Edit | Label Change (replace default label)
- Show Coordinates (default off) labels points in Coordinate geometry with ordered pairs. See also Options | Hide Coordinates.
- Filled objects (default off) will have their interior shaded according to the "Select Fill Color" palette (default gray).
- Visible (default on) is only accessible within the Default Style window (Options | Default Settings).
- The Font Size (default 12) of labeled objects can be increased or decreased.
- Thickness (default thin) of edges can be made thicker and Edge Color (default black) can be changed by using the "Select Color" palette.

Default Styles and Settings

The main difference between Synthetic and Coordinate Geometry environments is the Grid Style (see Options | Grid Style). The Grid and Axes are off (not shown) for Synthetic and on (visible) for Coordinate. In a *Coordinate* Geometry Environment the following settings are applicable:

- Options | Snap to Grid (default on) restricts the drawing of points to grid marks. When not checked plot points with non-integer coordinates.
- Options | Hide Coordinates (default off) will hide (or show) all coordinates at once. Use

Edit | Change Style of Selected to be more selective about which coordinates to show/hide.

- Options | Grid Style (default on) allows one to modify the grid points, thickness, style, and color of grid marks.

> Help Tip: Coordinate Labels are ordered pairs attached to points plotted in the coordinate plane and are a stylistic aspect of the geometry environment. To compute with matrix representations of ordered pairs select the desired object(s) choose Measurements | Coordinates.

- Options | Window Scale (default 20: [-10, 10]) takes a positive numerical value to set the viewing range of the screen for both x- and y-axes (the screen will always be symmetrical about the origin).
- Labels of drawn objects are shown by default. For a selected object, choose Options | Hide Labels or Edit | Label Change. For Label Change, the current name is in the left-hand column, the new name is typed into the right-hand column. Close the window to change the label.

> See also Style Window (Edit | Change Style of Selected *OR* Options | Default Settings).

- Hide/Show or Delete a selected object using the appropriate Edit menu option (Edit | Hide Selected, Show Hidden, Delete Selected).

> Note: Show Hidden will make all previously hidden objects visible. Delete Selected is permanent and cannot be reversed.

- Edit | Undo ( ) reverses the most recently performed action(s).

> Note: Deleted objects cannot be shown again. To temporarily hide/show objects use Edit | Hide Selected.

Programming and Animation

Execute a sequence of commands to draw, construct, transform, and otherwise manipulate objects in the plane.

> Note: Although the Options | Command Window is accessible through the *Synthetic* environment, commands typically reference the coordinates of an object. It is therefore suggested that the *Coordinate* environment be used for programming.

> See also Available Commands for Geometry.

Getting Started

There are several avenues to pursue programming within Interactive Geometry. Some are listed below:

- Use the Design by Robot Custom App to test the use of simple commands to move the robot around the screen (e.g., `fd 10 rt 90` to move forward 10 units and turn 90 degrees).
- Create a drawing or construction within Interactive Geometry. Choose File | Save and use the .txt extension. Open this saved file within a Text Editor program on your computer. Read through the programming commands that were used to create the drawing you made. Also open a saved text file within Interactive Geometry.
- Type into the Command Window (press Enter to execute a command).

> To view the command window Choose Options | Command Window, or move your cursor to the bottom of the screen and drag up from the small circle.

- Type the `program` command (followed by a space and the name of your program) into the Command Window to work within the Program Editor. Close this window then call the program by typing its name. This is especially useful for longer programs or animations. For example:

> ```
> program animateMe
> ```
> (type program into programming window, then close window)

```
animateMe
```

See also programming Basics.

Basics

- See the Available Commands for Geometry.
- Do not use reserved words such as `point` or `circle` to name objects or programs. For example, a good command would be `let pointA=point [0,0]` (the name of the point is "pointA"). Other reserved words include but are not limited to:

```
draw, polygon, point, segment, ray, line, halfplane, circle, angle,
parallel, perpendicular, intersection, midpoint, clear, let, cs, info,
show, reflect, rotate, translate, scale, visible
```

- A space " " should follow all reserved word commands.
- Square brackets are used to enclose commands and ordered pairs (e.g., `let segmentAB=segment [[0,0][5,3]]`, `let M=[midpoint segmentAB]`).
- `let` and `draw` (or `visible`) are basic commands to define and show objects.
- Clear the screen (`cs`) or the screen and command window contents (`clear`).
- The information or coordinates of an object can be shown on the screen (`info`) or within the command window (`show`).
- Commands for defining and drawing common objects include: `angle`, `circle`, `halfplane`, `line`, `point`, `polygon`, `ray`, `segment`, `vector`.

  See also Drawing using the menubar/toolbar.

- Construction commands include: `bisect`, `intersection`, `midpoint`, `parallel`, `perpendicular`, `tangents`.

  See also and Constructions using the menubar/toolbar.

- Transformation commands include: `reflect`, `rotate`, `scale`, `translate`.

  See also Transformations using the menubar/toolbar.

- Additional commands include: `input "Prompt" variable`, `path point`, `[function expression]`.

  Note: Common functions that can be used with the `[function expression]` syntax include `abs`, `cos`, `invcos`, `invsin`, `invtan`, `sin`, `sqrt`, `tan`.

Animation

An animation is a sequence of programming commands that often involves drawing, constructing, and transforming objects in the plane. For ease in executing several commands at once, use the `program` command.

Consider the following annotated example of a simple animation using scale transformations. Note that with this option, few lines of code are typed into the Command Window. Most coding is done in a separate Program Window which allows for greater flexibility and editing of a sequence of commands.

```
program growShrink
```

- A new window with title growShrink will appear.

```
cs
let wheel = [circle [[0,0][1,0]]]
Style wheel visible on fillcolor 255 0 0 filled on
repeat 10 [draw [let wheel = [scale wheel 1.3]] pause 100]
repeat 10 [draw [let wheel = [scale wheel .77]] pause 100]
end
```

- Enter the program commands into the new window. Close the window when finished.

```
growShrink
```

- To run the program, type just the name into the Command

```
to growShrink
```

Window.

- To edit the program, type the `to` command followed by the name of the program. Alternatively, type the `program` command followed by the name of the program. The Program Window will be shown.

Geometry & Trigonometry Custom Apps

The Geometry & Trigonometry Custom Apps embed dynamic 2D and 3D shapes and animations. Click on the name of a tool below for a description and related help topics:

2D

Polygons & Transformations	*Angles, Arcs, & Measure*	*Programming & Animation*
Explore Similar Triangles	Explore Angles and Arcs	Design by Robot
Explore SSA	Explore Radians	
Tilings with Regular Polygons		
Tilings with Triangles or Quadrilaterals		
Triangle Congruence		

3D

Slicing a Double Cone	Slicing or Unfolding Polyhedra	Surface of Revolution

Design by Robot

Create both simple and complex designs by entering program commands for the robot to draw and move.

Note: See also Programming and Animation, and Geometry Commands.

Instructions:

1. Type Robot Commands into the command window to instruct the robot to move and draw.
2. Press return on the keyboard to execute a typed command or list of commands.
3. You may create procedures to carry out entire lists of commands at once.

Robot Commands

Type individual or lists of robot commands into the command window at the bottom of the *Interactive Geometry* screen. Remember to press return.

Action / Explanation	Command	Example
Move robot forward # units	`forward # / fd #`	`forward 15 / fd 15`
Move robot backward # units	`back # / bk #`	`back 25 / bk 25`
Turn (rotate) robot to the left (counterclockwise) # degrees	`left # / lt #`	`left 90 / lt 90`
Turn (rotate) robot to the right (clockwise) # degrees	`right # / rt #`	`right 60 / rt 60`

Put the pen up (do not draw)	`pu`	`fd 5 pu fd 5 pd fd 5`
Put the pen down (draw)	`pd`	`repeat 2 [rt 90 fd 5 pu rt 90 fd 5 pd]`
Clear the drawing on the screen (does not move the position of the robot)	`cs`	`cs repeat 3 [lt 120 fd 4]pd`
Return robot to origin/starting position (does not clear drawing)	`home`	`fd 8 home rt 90 fd 8`
Hide robot	`ht`	`repeat 5 [rt 72 fd 4] ht`
Show robot	`st`	`st`
Repeat a command the desired # of times	`repeat # [command(s)]`	`repeat 8 [fd 3 rt 45]`
Delay the execution of a command by #	`pause #`	`repeat 3 [fd 10 rt 120 pause 500]`

Help Tip 1: Put a space between the command and the numerical value(s) associated with the command.

> *Correct Example:* `fd 15 lt 270`
>
> *Incorrect Example:* `fd15lt270`

Help Tip 2: If you get an error message such as `>I don't know how to ...` check the spacing and spelling of your commands; revise and try to execute again.

Help Tip 3: If you get an error message such as `>Not enough parameters!` check that you have a space and a numerical value after appropriate commands (see Robot Commands with #'s); revise and try to execute again.

Help Tip 4: The robot can also do arithmetic. For example, type `rt (270-45*2)`.

Create Procedures

Carry out entire lists of commands at once by creating a procedure.

1. Type `to` in the command window followed by a single space then `nameprocedure`.
2. Press Enter on the keyboard to execute the script in Step 1. A program window will automatically open.
3. Type in the program window the commands you wish to include in your procedure.
4. Close out of the program window by clicking on the X in the upper corner of the window bar.
5. Run your procedure by typing `nameprocedure` in the command window.

Example:

Command	Explanation / Result
`to squares`	Type in command window; computer recognizes the creation of a procedure referenced by the word or called "squares"

`cs home`
`repeat 4 [fd 4 rt 90 pause 550]`
`repeat 4 [fd 8 rt 90 pause 550]`
	Type in the program window; these are the commands that the procedure "squares" will carry out. *Be sure to close out of this window before moving on.

`squares`	Type in the command window; the defined procedure will automatically be carried out and the robot will draw two squares.

Explore Angles and Arcs

Explore the relationship between the measures of inscribed angles and their intercepted arcs.

Instructions:

1. Drag point *B*.
2. Click the "Show Measures" button to show the measures of angle *ABC*, angle *AOC*, and arc *AC*. Click "Hide Measures" to hide these measures.
3. Drag points *A* and *C* to consider right angle *ABC* and obtuse angle *ABC*.

Explore Radians

Experiment measuring angles in radians and how radian measures are related to degrees and revolutions.

Instructions:

1. Decide upon a target. Options for entering a target include:
   - Click on one of the "Enter Target in..." buttons for *Degrees*, *Revolutions*, or *Radians*. Type a value into the message window (type "PI"), then click Done. The target will move along the circle according to the specified value.
   - Click on the "Random Target" button. The target will move along the circle to a random location.
   - Drag the target along the circle.
2. Guess the target value. Click on one of the "Guess..." buttons for *Degrees*, *Revolutions*, or *Radians*. Type your guess into the message window, then click Done. To end the guess process, click Cancel.
3. Choose the "Show Measurements" button to display measures for the measure of angle BOT in degrees and radians, length of segment OB, and arclength of arc BOT. Click "Hide Measurements" to hide these values.

Explore Similar Triangles

Investigate the construction of pairs of similar triangles by applying the definition of similar triangles.

Instructions:

1. Select a scale factor by dragging point *K* along the slider between the values of 0 and 6.
2. Drag points *D*, *E*, and *F* so that triangle *DEF* is similar to triangle *ABC*.
3. Click the "Test if Similar" button to test if the two triangles are indeed similar. If so, the actual scale factor will be displayed above the target scale factor. If not, you will be prompted to go back to Step 2.
4. Once the triangles are similar, the program will create triangle *A'B'C'* for comparison to triangle

DEF. An animation of this transformation process will be displayed. Specifically, triangle *ABC* will be scaled by a scale factor of *K*, then translated, rotated, and reflected (as needed) until triangle *A'B'C'* coincides with triangle *DEF*.

5. Drag point *K* to observe how various scale factors for triangle *A'B'C'* compare to the actual scale factor relating triangles *ABC* and *DEF*.
6. Click the "New Triangles" button to generate a new case for investigation.

Explore SSA

Experiment with various side and angle measures to explore the Side-Side-Angle congruence condition for triangles.

Instructions:

1. Drag the red points to change the measure of angle *A*, or side lengths *AB* and *BC*.
2. To guide your investigation you may wish to determine for which measurements or intervals of measurement the given side-side-angle parts determine no triangle, exactly one triangle, two noncongruent triangles.

Slicing a Double Cone

Dynamically manipulate a plane slicing a double cone and view the corresponding conic section.

Conic sections are defined as the intersection of a plane and a right circular double cone. This custom app allows for the manipulation of the position of the plane (drag the tilt slider) and the view of the double cone (drag the cone itself) in order to examine the resultant intersection. The help topics below include information on: Slicing Plane Attributes and the Tool Menu.

Slicing Plane Attributes

- *Tilt (Angle from xy-plane)*: The tilt angle is determined by the angle formed between the xy-plane and the shaded plane shown. Notice that the 2D rendition of the angle and the conic section dynamically update as the tilt is changed.

  Note: To adjust the Settings, choose the red box to view the Configuration Panel in order to set minimum and maximum values for the tilt angle. Unit and block increments can also be adjusted. Click OK to make these changes or Cancel to exit without change.

- *Vertical Translation*: Drag the horizontal slider bar to adjust the vertical translation of the plane that cuts across the double-cone.

  Note: To adjust the Settings, click the red box to set minimum and maximum values for the vertical translation of the plane. Unit and block increments can also be adjusted. Click OK to change these settings or Cancel to exit without change.

- Choose Wire Frame from the Options menu to show the frame of the double cone instead of the shaded surface.

- Choose Label Conic from the Options menu to show labels of the type of conic section shown on both the 3D View and the Standard View.
- Choose Extend Double Cone or Shrink Double Cone from the Options menu to adjust the size of the double cone in the 3D View.

Tool menu

The Tool menu offers options to Restart, Print, and Close the custom app.

- Choose Tool | Restart to reset the viewing window to the original display.
- Choose Tool | Print to print the current view of the slice.

  See also Save & Print.

- Choose Tool | Close or the X button to close this custom app.

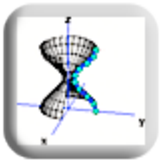
Slicing or Unfolding Polyhedra

Visualize common polyhedra and manipulate 3D modeling options such as cutting and unfolding.

Instructions

1. Set up the model by choosing a solid from the Polyhedron menu.
2. Adjust the graph view.
   - Click and drag the shape on the screen to rotate it in the 3D space.
   - It might be helpful to adjust the transparency of the shape before manipulating.
   - Choose to View | Zoom In , Zoom Out , and Zoom Fit .
   - The Vertices, Edges, and Faces of a solid can be shown or hidden by selecting (or deselecting) them in the View menu.
3. Model the slicing or unfolding of the selected polyhedra.
   - Choose Enable in the Cut, Unfold, or Transform menus.
   - Drag the available slider bars to adjust the model accordingly
4. Use the Tool menu to save, print, or otherwise record your work.

   See also Save & Print.



Surface of Revolution

Draw and manipulate a line or connected series of line segments in two-dimensional space to simultaneously generate a surface of revolution in three-dimensional space.

A *surface of revolution* is a surface formed by rotating (revolving) a curve about a line. The help topics below include information on: the Draw Tools for defining lines and curves, the Revolution Settings for setting the angle and axis of revolution, the Tool menu, and Options menu.

Draw Tools

- Choose to Clear All in the current drawing(s) and reset the axis to the original position. Alternatively, choose Tool | Restart to obtain the original starting view, settings, and graph.

- Choose the Draw tool to define a new curve or line. Click and release the mouse over the 2D coordinate grid to define points. Points will automatically be connected with a segment to the point preceding it. Another drawing technique is to click and drag as you hold the mouse button down.

  Dynamic Drawing: Notice that as points are drawn on the coordinate grid, the surface of revolution is correspondingly defined in the three-dimensional space.

- Use the Select tool to click on and drag defined points to new locations on the coordinate grid. Observe how the 3D surface of revolution automatically updates.

Revolution Settings

- *Angle of Rotation*: Drag the slider bar as the angle of rotation for the surface of revolution is dynamically updated.

  Note: The default setting for the angle of rotation is 180° and ranges from 0° to 360°. Click the red box to the right of this slider bar to set different minimum and maximum values, and indicate the unit and block increment. Click OK to update the settings or Cancel to exit without changing the settings.

- *Axis of Rotation*: Choose the or buttons to change the axis of rotation to the y- or z-axis, respectively.

Tool menu

The Tool menu offers options to Restart, Print, and Close the custom app.

- Choose Tool | Restart ( ) to obtain the original starting view, settings, and graph.
- Choose Tool | Print to print the currently selected frame.

  See also Save & Print.

- Choose Tool | Close or the X button to close this custom ap. Return to the main screen to make a new tool selection.

Options menu

The Options menu allows you to modify the display of the 3D surface of revolution.

- Choose Options | Show Edges to toggle the wireframe of the surface of revolution.
- Select Options | Show Surface to toggle the quadrilateral faces that comprise the surface of revolution.
- Choose Options | Show Meridian to toggle the 2D curve used to sweep out the surface of revolution.
- Choose Options | Show 3D Axes to toggle the x-y-z coordinate axes.
- Choose Options | Rotate about Horizontal Axis or the button to perform the revolution about the y-axis rather than the z-axis.
- Choose Options | Rotate about Vertical Axis or the button to perform the revolution about the z-axis rather than the y-axis.

Tilings with Triangles or Quadrilaterals

Explore tiling the plane with triangles or quadrilaterals using rotations of 180 degrees about midpoints of sides.

Instructions:

1. In the Shape menu, choose to tile using Triangles or Quadrilaterals. You may change the shape at any time.

   Note: Only one shape may be used at a time and if you choose a new shape it will clear and replace the current drawing.

2. Drag any vertex to change the shape of the figure.
3. Click on or near the midpoint of an edge of the figure. This rotates a copy of the figure 180° about the midpoint of the edge and attaches the rotated copy to that edge.
4. Repeat Step 3 several more times – at least until you have completely surrounded the original figure including all of its vertices with copies of the figure.
5. As you build a tiling, you may need to know:
   - Remove the last polygon placed by choosing Undo in the Edit menu or the Undo button on the toolbar.
   - Clear the current drawing and start over by choosing Restart in the Tool menu, Clear in the Edit menu, or the button on the toolbar.
   - Change (or turn off) the rotation animation by choosing Fast, Slow, or Off in the Edit menu under the sub-option Animation.
   - Print the current tiling by choosing Print in the Tool menu or the button on the toolbar.

Tilings with Regular Polygons

Explore tiling the plane with regular polygons to create regular and semiregular tessellations.

Instructions

1. Choose the number of sides of the regular polygon that will be placed next by clicking on the button to the left of that number at the top of the window.
2. Click anywhere in the blank window to place the first polygon.
3. To attach a new polygon to one already placed, choose the number of sides (see Step 1) then click near the edge of the polygon to which you want it attached.

   Remember: As you build the tiling, there should be no gaps and no overlaps.

4. As you attach more and more polygons to build a tiling, you may need to know:
   - Remove the last polygon placed by choosing Edit | Undo or the Undo button on the toolbar.
   - Delete a polygon by clicking in the center of it then choosing Edit | Delete Polygon or the button.
   - Scale the tiling (make it larger or smaller) by using the Zoom slider.
   - Clear the current drawing and start over by choosing Tool | Restart, Edit | Clear, or the button.
   - Print the current tiling by choosing Tool | Print or the button on the toolbar.

   See also Save & Print.

Original applet written by Melinda Green and Don Hatch, modified by S. Keller.

Triangle Congruence

Explore combinations of side or angle measures that determine the existence of a unique triangle (or the congruence of two triangles). Test for congruence with measurements or an animated transformations approach.

Instructions:

1. Select a possible condition for congruence of triangles from the "Select a Condition" drop-down menu.

   Options include: Side-Angle-Side, Side-Side-Angle, Angle-Side-Angle, and Side-Side-Side.

2. Angle/side measures will be generated for you and these measures determine the figure drawn on the screen.

   You may choose to enter your own side/angle measures by typing values into the boxes to the right of the drop-down menu. Be sure to press Enter to construct a triangle with these fixed measures.

   Alternatively, click the button for the Custom App to generate a different set of measures for you.

3. With the desired fixed measures set, try to build a triangle by dragging the blue colored vertices and/or the lengths of the ray(s).
4. The labels of the triangle vertices (A, B, and C) will automatically appear on the screen when a triangle has been formed.

   Note: Choose Options | Show Measurements to display the remaining side and angle measures of the constructed triangle.

5. If possible, create a second triangle with the same set of chosen measures by repeating Steps 3 and 4.
6. Compare the measurements and/or shape and size of the two formed triangles. Are the triangles congruent?
   - To test by transformations, choose the button to play the first step in a sequence of transformations. Continue until the triangles coincide (if possible). Choose the to reset the triangle positions and test again.

     Use the Options menu to customize the ways triangles are created and tested to be congruent. For instance, show the transformations as a step through sequence or animation.

     Use the Test by Transformations menu to specify the sequence of transformations that is performed. For instance, use only reflections or a sequence of reflections.

   - Move the second formed triangle (shaded in red) until it coincides with the first by clicking and dragging. Dragging from the center of the figure will move its positions on the screen, dragging from a vertex will rotate it about that vertex. Additionally, use the button or simply double-click on one of the triangles to reflect it.
7. Repeat Steps 2-6 several more times until you have a few cases for your chosen condition.

Geometry & Trigonometry Quick Links:

Geometry & Trigonometry Index

All help topics and commands that are available within the Geometry & Trigonometry strand of tools are listed below in alphabetical order.

[abs number]
Add Vectors
Angle, angle
Angle Measure
Angle Bisector
Animation
Area
bisect
Calculate, Calculation
Change Style of Selected
Circle, circle
Circumference
clear
Command Window
Constructions
Coordinates
Coordinate Geometry
[cos number]
cs
Custom Apps
Delete Selected
Default Settings
Default Styles
Design by Robot
Draw, draw
Edit menu
Explore Angles and Arcs
Explore Radians
Explore Similar Triangles
Explore SSA
Figure or Polygon
Filled, Fill Color
Font
[function expression]
Grid Style
Half Plane, halfplane
Hide Coordinates
Hide Selected
info
input "Prompt" variable
Intersection, intersection
[invcos number]
[invsin number]
[invtan number]
Labels
Lengths
let
Line, line
List of Shapes
Measure
Menubar
Midpoint, midpoint
Options menu
Parallel, parallel
path point
Perimeter
Perpendicular, perpendicular
Point, point
Polygon, polygon
program
Programming
Ray, ray
Reflect, reflect
Rotate, rotate
Scale, scale
Segment, segment
Select
show
Show Coordinates
Show Hidden
[sin number]
Slicing a Double Cone
Slicing or Unfolding Polyhedra
Slopes
Snap to Grid
[sqrt number]
Style Window
Surface of Revolution
Synthetic Geometry
[tan number]
Tangents, tangents
Thickness
Tilings with Regular Polygons
Tilings with Triangles or Quadrilaterals
Toolbar
Transformations
Translate, translate
Triangle Congruence
Undo
Vector, vector
Visible, visible
Window Scale

Geometry Commands

Programming commands with examples for Interactive Geometry are listed below in alphabetical order.

Note: If you copy and paste an example into the Command line, press Enter at the end of each line. Otherwise, use the `program` command and copy and paste into a program window.

See also Getting Started, Programming Basics, Catalog, Geometry Index.

Command	Explanation	Example(s)
`[abs number]`	Compute the absolute value of a given number	`let a=[abs -6]` `show a returns 6.0`

`angle [p1,p2,p3]`	An angle is determined by three points (with the second point as the vertex), and is swept out counterclockwise from the first toward the third	`let p1=[point [0,0]]`
		`let p2=[point [5,0]]`
		`let p3=[point [3,3]]`
		`let angle123=[angle [p1,p2,p3]]`
		`draw p1 draw p2 draw p3`
		`draw angle123`

`bisect angle1`	Construct the bisector of a given angle	`let angleABC=angle [[4,4][-5,3][-5,11]] draw angleABC`
		`let bisectangleABC=[bisect angleABC]`
		`draw bisectangleABC`

`circle [p1,p1]`	Define a circle by a center point and a point on its radius	`let point1=point [0,0] draw point1`
		`let point2=point [5,0] draw point2`
		`let mycircle=circle [point1,point2]`
		`draw mycircle`

`clear`	Erase the entire screen and command window contents	`clear`
`[cos number]`	Compute the cosine of a given number	`let c=[cos 0]` `show k returns 1.0`
`cs`	Erase the screen contents only	`cs`

`draw object`	Makes a previously defined object visible on the screen	`let A=point [1,1]`
		`let B=point [0,-5]`
		`draw A`
		`draw B`

`[function expression]`	Execute a function for a given expression (where function is the name of a common function)	`let A=[sqrt 49]`
		`show A`
		`returns 7.0`

`halfplane [p1,p2]`	Define a half plane by two points on its line	`let point1=point [0,0] draw point1`
		`let point2=point [5, 0] draw point2`
		`draw halfplane [point1,point2]`
		`draw halfplane [point2,point1]`

`info`	Show the coordinates of a defined object as a measurement on the screen	`let A=point [3,4]`
		`info A`
		`draw A`

`input "Prompt" variable`	Call an input window and give a value to the variable "Prompt"	`input "Prompt" variable` returns a window, type 5, Done.

`intersection object1 object2`	Define the intersection of two previously defined objects	`let lineAB=line [[3,0][8,5]]`
		`let lineCD=line [[0,0][5,-3]]`
		`let E=[intersection lineAB lineCD]`
		`draw lineAB draw lineCD draw E`

`[invcos number]`	Compute the inverse cosine of a given number	`let ic=[invcos 1]` `show ic returns 0.0`
`[invsin number]`	Compute the inverse sine of a given number	`let is=[invsin 0]` `show is returns 0.0`
`[invtan number]`	Compute the inverse tangent of a given number	`let it=[invtan 0]` `show it returns 0.0`
`let`	Define and name objects for use, the characters that follow the let command represent the name of the object	`let origin=point [0,0]` `draw origin`

`line [p1,p2]`	Define a line by two points	`let point1=point [0,0] draw point1`
		`let point2=point [5,0] draw point2`
		`let line1=line [point1,point2]`
		`draw line1`

`midpoint object1`	Construct the midpoint of an object (e.g., a segment or polygon)	`let AB=[[-7,7][13,1]]`
		`let CD=[[3,8][3,2]]`
		`let M=[midpoint AB] show coord M`

`parallel point1 line1`	Determine a parallel line through a given point to a given line	`let line1=line [[0,0][1,1]]`
		`let point1=point [-2,0] draw line1`
		`draw point1`
		`let line2 =[parallel point1 line1]`
		`draw line2`

`path point`
`path point point`
	Determine the path of a given point	`let P=[point [0,0]]`
		drag point P on the screen to a new location then
		`show path point P`
		`> pathpoint[3.0, -9]`

`perpendicular point1 line1`	Determine a perpendicular line through a given point to a given line	`let line1=line [[0,0][1,1]]`
		`let point1=point [-2,0] draw line1`
		`draw point1`
		`let line3=[perpendicular point1 line1]`
		`draw line3`

`point [x,y]`	Define a point determined by an ordered pair in square brackets [x-coordinate, y-coordinate]	`let A=[point [2,7]]` `draw A`

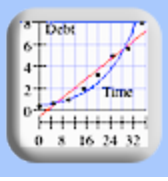
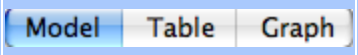
`polygon [p1,p2,...,pn]`	Determine a polygon or shape by a finite number of points	`let R=point [2,7]`
		`let S=point [0,0]`
		`let T=point [-2,-2]`
		`let shapeRST=polygon [R S T]`
		`draw R draw S draw T`
		`draw shapeRST`

`program`	Type the `program` command (followed by a space and the name of your program) into the Command Window to work within the Program Editor. Close this window then call the program by typing its	`program animateMe`
		(type program into programming window, then close window)
		`animateMe`

	name.	
ray [tail,head]	Define a ray by a tail and a head	draw ray [[5,0],[8,6]]
reflect object1,line1	Reflect a previously defined object over a previously defined line	let A=point [4,4] let B=point [7,12] let C=point [-1,2] let lineDE=line [[5,4][10,4]] let triangleABC=polygon [A B C] let A'=[reflect A lineDE] let B'=[reflect B lineDE] let C'=[reflect C lineDE] let triangleA'B'C'=polygon [A' B' C'] draw A draw B draw C draw triangleABC draw lineDE draw A' draw B' draw C' draw triangleA'B'C'
rotate object1 angle1	Rotate an object to be rotated by a specified angle (either numerical or as a defined object)	let triangleABC=polygon [[4,5][1,7][4,-2]] draw triangleABC draw rotate triangleABC 45
scale object1 vector1 scale object1 scalefactor	Scale an object by a vector or scale factor, centered at the origin	let A=point [-6,6] let B=point [-8,0] let C=point [-3,4] let triangleABC=polygon [A B C] let A'B'C'=[scale triangleABC 1.5] draw triangleABC draw A'B'C'
segment [p1,p2]	Define a segment by two endpoints	let segAB=[segment [[0,0],[5,0]]] draw segAB
show	Show the coordinates of a defined object within the command window	let segAB=[segment [[0,0],[5,0]]] let M=[midpoint segAB] show M
[sin number]	Compute the sine of a given number	let s=[sin 0] show s returns 0.0
[sqrt number]	Compute the square root of a given number	let k=[sqrt 57] show k returns 7.5498344
[tan number]	Compute the tangent of a given number	let t=[tan 0] show t returns 0
tangents circle1 point1	Construct tangents to a circle through a point on or off the circle	let A=point [-9,5] let B=point [-4,9] let circleAB=circle [A B] draw A draw B draw circleAB let tcircleABB=[tangents circleAB B] draw tcircleABB
translate object1 vector1	Translate an object by a translation vector (either an ordered pair or as a defined object such as a segment).	let A=point [-6, 6] let B=point [-8, 0] let C=point [-3, 4] let triangleABC=polygon [A B C] let seg1=segment [[0,0][5,0]] let imag1=[translate triangleABC [8,0]] let imag2=[translate triangleABC seg1] draw triangleABC draw imag1 draw imag2
vector [tail,head]	Define a vector by a tail and a head	draw vector [[-2,0],[-3,3]]
visible	together with the style command, make an object visible or hidden with "on" or "off"	let object=[segment [[-5,1][5,2]]] style object visible on

Statistics & Probability

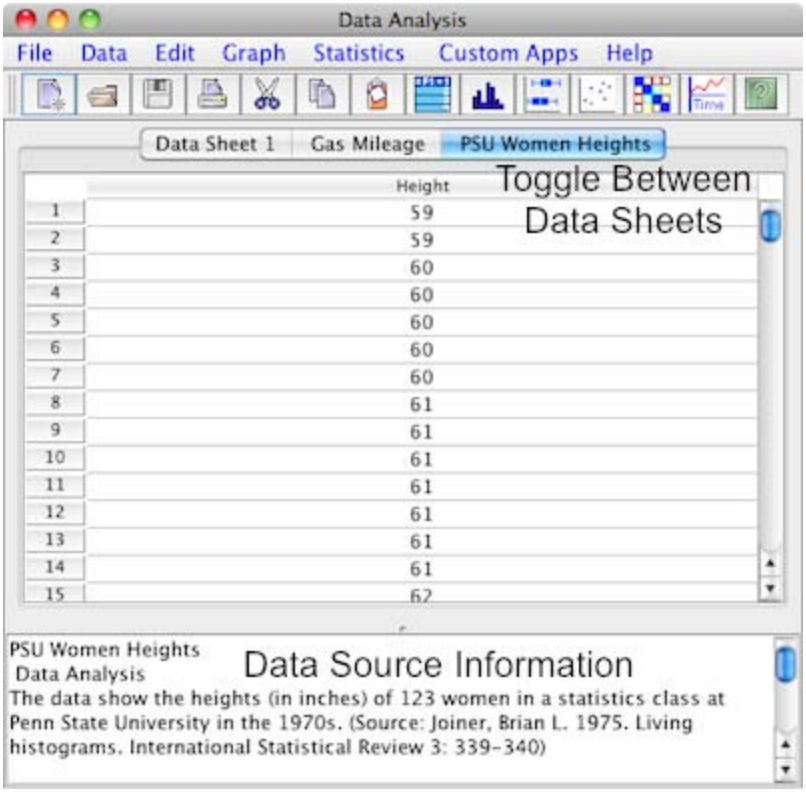
Data Analysis and Simulation are tools designed for the Statistics and Probability strand. The focus of Data Analysis is on the graphical and numeric display of univariate and bivariate data. Simulation can be used to create and run simulations of probabilistic situations.

Data Analysis	Data Sheets	Graphs	Statistical Analysis
			
Analyze data in graphical and numeric displays.	Display and compute data stored in a grid, and relate rows and columns by formulas.	Plot data as a histogram, box plot, scatterplot, matrix plot, or time series plot.	Perform statistical calculations, regression analysis, and model sampling distributions.
Simulation	**Build and Run**	**View and Analyze**	**Custom Apps**
			
Model probabilistic situations and analyze the results in tables, graphs, or data sheets.	Create an event and customize a simulation with computations, then control the speed, start, and stop.	Customize the display of simulation results in the Model, Table, and Graph and compute basic statistics.	Explore univariate and bivariate data in graphical environments for shape, center, and spread of a distribution.
Index	**Catalog**	**Settings**	**Save & Print**
Browse help topics specific to Statistics & Probability in A-Z order.	Comprehensive catalog for Core Math Tools.	Adjust Data Analysis settings to modify stylistic attributes of created objects.	Core Math Tools (CMT), Image (GIF) and Text (TXT) are file types.

See also Help Topics at a Glance or Go Online for Additional Resources.

Data Analysis

Use the Data Analysis tool to analyze univaritate and bivariate data in graphical and numeric displays.



A Data Analysis data sheet is like a spreadsheet environment with statistics related functionality.

Data

To modify or edit a pre-loaded data set, choose Edit | Enable.

Choose a data set from the Data menu for quick access to pre-loaded data examples.

> See also Data Sets, Spreadsheet.

Edit Styles and Settings

Help topics for Edit menu options including Cut, Copy, Paste, Fill Down, Set # of Digits, Column Name, and Column Formula are common across Spreadsheet and Data Analysis.

> Note: Some functionality is available within Spreadsheet and not in Data Analysis (e.g., Sort, Delete and Insert rows/columns).

> Note: Settings for graphs are available within the Options menus once a plot is shown.

Graphical Displays

Options for Graphical Display (see Graph menu) include those for univariate and bivariate data display, statistical plots, and frequency tables. Link to additional help contents and settings for each graph type:

Univariate	Bivariate	Statistical	Frequency Table
• Histogram	• Scatterplot	• Times Series	• Histogram
• Box Plot	• Matrix Plot	• Normal Plot	• Box Plot

See also Save & Print.

Note: The Tools menu of each graph window gives options to Copy a graph image to a clipboard to paste into another application (e.g., Text Editor). Also choose to view Tool | Basic Statistics for the plotted data.

Histogram

Use a single column, or Control+Click to select more than one column of data for a "stacked" Histogram.

- Choose Options | Relative Frequencies to display relative frequencies (percent) above each histogram (the vertical axis will reflect this labeling scheme). Otherwise, the frequency (number of items) is displayed.

  Note: If Options | Label Bars is not checked, individual histogram bars will not be labeled yet the vertical axis labeling will match the appropriate selection.

- Other entries of the Histogram Options menu change the default appearance of the plot. They are displayed when checked, or hidden otherwise. These include: Labels, Grid, Standard Deviation.
- Histogram settings can be modified by typing or dragging at the bottom of the plot window. Change the "Min X" or minimum value in a data set that will be included in the plot. Press enter. Also change the "Bin Width" to set the width of all histogram bars.

Box Plot

Use a single column, or Control+Click to select more than one column of data for a "stacked" Box Plot.

- To change the default appearance of the box plot, select an entry of the Options menu.
- When Options | Outliers is checked any existent outliers will be displayed as distinct points.
- When Options | Horizontal is checked the plot is oriented horizontally.

Scatterplot

Two columns must be selected to plot Scatterplots; one independent and one dependent column are required.

- Excluded : First select a data point (highlighted in blue) then choose to remove that data point from the plot (highlighted in red).

  Note: If the Options | Show Equation(s) is checked when points are excluded (or included) the regression equation(s) will adjust accordingly, with the most recent equation in blue - the others in red.

- Draw Moveable Model : Show or hide a moveable line to estimate the best-fit curve for the data. Click and drag the green squares to alter the position and shape of the model.
- Draw Regression Model : Show (or hide) the regression model (of the chosen type) on the scatterplot.
  - First choose one regression model type from the Models menu (deselect all others). Then choose .
  - While one regression model type is drawn, you may add other types of models by selecting them from the Models menu.

The most recently drawn regression model is colored in blue and all previously drawn regression models are in red.

Note: Regression models are not moveable, but will be reformulated and drawn if points are removed/excluded (or re-included).

See also Moveable Model.

- Draw Residuals : Show (or hide) the residuals for a drawn moveable model ( ) and the most recently drawn regression model ( ). At least one regression model or a moveable line must be drawn for residuals to be plotted.

  See also Statistics | Regression, Models | Analysis.

- Draw Squares : Show (or hide) the squares of the residuals for a drawn moveable model ( ) and the most recently drawn regression model ( ). At least one moveable model or a moveable line must be drawn for squares to be plotted.

  See also Error Thermometer.

- Draw Means $\bar{x}, \bar{y}$: Show (or hide) horizontal and vertical lines representing the *x* and *y* means for the plotted data. Move the mouse cursor over the intersection of these red lines to give the ordered pair of the means.

  Note: If a data point is excluded ( ) the means will adjust accordingly.

- Choose Options | Show Equations to show (or hide) the equations of any drawn moveable or regression models on the scatterplot. The equations will be colored-coded to match the model they represent.
- Select Options | Show Predicted Value(s) to show (hide) a table of predicted values corresponding to all drawn regression ( ) and moveable ( ) models in a separate window. At least one regression model or a moveable line must be drawn for residuals to be plotted. Click on a table entry and use the arrow keys on your keyboard to move through the table of values; notice the corresponding point and coordinates are highlighted in the scatterplot window.

  Note: The range of x values that are used within the scatterplot window will be used by default for the Predicted Values window. Type numerical values into the Min x, Max x, and x Step boxes and press Enter after typing in each box to change these settings.

- Choose Options | Error Thermometer to show (or hide) a depiction of the sum of the squared errors (SSE) for the drawn models to the right of the scatterplot. This option is useful when comparing the SEE of the moveable model with the SEE of the regression model.

  See also Draw Squares.

- Guess Correlation r=?: Show (or hide) the guess correlation bar to the right of the scatterplot. Select a guess for *r* from one of the five options available then click Show r to view the actual correlation value.

  Note: Although you can calculate a correlation for any scatterplot, r measures only straight-line (linear) relationships.

- Plot Information : Show (or hide) scatterplot information. Options include those for modifying labels for *x* and *y*, viewing basic statistics for the plotted data, naming the plot (or title), and adjusting window settings. Additionally, you may check options to Show Correlation, Show SEE, and Show Confidence Bands.
- The Scatterplot | Models menu allows you to select (or deselect) the type of model that is drawn on a scatterplot. The chosen model applies to both Moveable ( ) and Regression ( ) models.
- Choose Models | Enter/Edit a Model to type your own model type in "*y* = ..." form. If such a model has already been drawn, choosing this menu option will allow you to edit the previously-entered model.

  Note: The program will not accept your model if you type "y=" in the Enter/Edit a Model window. Instead, enter the rest of the model, without the "y=" then click OK.

- Analysis : Analyze a plot of the independent variable and the plot of residuals in a separate window. Within this Residual Plot(s) window:
  - The Tool menu gives options to view Basic Statistics, Print, or Save the residual analysis.
  - Choose an entry from the Options menu to change the view of the residual plot. The default view of Residual vs. X is selected, when other options are selected they will be added to the right of the original selection. Menu entries include: Residuals vs. X, Residuals vs. Y, Residuals vs. Order, Normal Probability Plot, and Regression Analysis.

Matrix Plot

Two or more columns must be selected to plot a Matrix Plot.

Time Series

At least one column of data must be selected to plot a Time Series graph (multi-column graphs will be color-coded).

Normal Plot

At least one column of data must be selected to plot a Normal Plot graph (multi-column graphs will be color-coded).

Frequency Table | Histogram, Box Plot

There are two options for frequency tables: Histogram, and Box Plot. To use these plot options, the values of frequency table should be listed in one column, with their corresponding frequencies in another column.

Statistical Analysis

Descriptive Statistics

Choose Statistics | Descriptive Statistics to view summary statistics for the columns of an active data sheet. The following calculations are given for each column:

> n (number of values in the column), Mean (arithmetic average), Minimum (smallest value), Q1 (first quartile), Median (middle value of ordered list), Q3 (third quartile), Maximum (largest value), Sample Standard Deviation (a measure of spread), Sample Variance (the square of the standard deviation).

Chi-Square Test

To use the Chi-Square Test:

1. First open or create your own bivariate categorical data set (e.g., Crying).
2. Choose Statistics | Chi-Square Test to open a Chi-Square Analysis window to obtain the chi-squared statistic.
   - Use the Tests menu and choose to Test for Independence, Test for Homogeneity, or determine a Goodness of Fit.
   - Use the Options menu to Show Expected Counts, Show Expected Percents, or Show Critical Values.

Randomization Distribution

Create an approximate sampling distribution of possible differences in means, medians, or standard deviations of two treatments by rerandomizing, then identify extreme events.

See Statistics & Probability Custom Apps.

Distribution of Sample...

Explore the shape, mean, and standard deviation of distributions of sample means, medians, or standard deviations for various sample sizes.

See Statistics & Probability Custom Apps.

Regression

Within an open data set, choose a regression type (e.g., linear) from the Statistics menu. Within the Choose Columns window, select one column for each of the independent and dependent variables. Click OK to approve the choices and view the Regression Analysis Frame. Several options are available within this frame:

- The Results tab lists all regression statistics for the chosen regression type (e.g., Linear) including: Sample Statistics, Coefficient Estimates, 95% Confidence Intervals, and Analysis of Variance.
- The Graph tab shows a scatterplot of the data along with the chosen regression model, shown in red. The regression equation is shown above the graph.
- The Residuals tab shows a plot of the residuals on the scatterplot of the data. A time series plot of the data is also shown within this tab.

Simulation

Use the Simulation tool to model probabilistic situations and analyze the results in tables, graphs, or data sheets.

Basics

Create simulations that model simple situations such as flipping a coin, rolling a die, drawing a card, or generating a random integer. Summarize the results in table form or in histograms. Additionally, view basic statistics or analyze the results in Data Analysis.

Getting Started

1. Build a simulation.
2. Run a simulation ▶.
3. View and analyze results within Simulation or Data Analysis.

Build a Simulation

Use the Options menu or toolbar icons to create events and customize simulations with computations. Choose to build a Simple/Common Event or Distribution Event, create a Custom Event, relate events by Computations, model Meta Events, and view a Sample Simulation.

- Simple/Common Events: Click on a toolbar icon (shown below) or its corresponding entry in the Build | Common Events menu or choose from Build | Other Simple Events to add a simple event to the simulation. Each time a simple event is chosen it will be added to the simulation.

Pick a card from 52-card deck	Roll a 10-sided die
Flip a 2-sided coin	Roll a 20-sided die
Roll a 4-sided die	Generate a random digit
Roll a 6-sided die	Generate a random integer from *a* to *b*.
Roll an 8-sided die	

- Distribution Events:
  - Choose Build | Distribution | Random Binomial to build a binomial situation with n=100 and p=0.5. To make changes to these default values, double-click near the text beginning with "Binomial." Type a value into either text box then press Enter to change the value of *n* (number of trials) or *p* (probability of success).
  - Choose Build | Distribution | Random Normal to build a normal distribution event with mean=0 and std dev=1.0. To make changes to these default values, double-click near the

text beginning with "Normal." Type a value into either text box then press Enter to change the value of the *mean* or *standard deviation*.

- Custom Events: Choose Build | Create Custom Event and double-click the "unnamed" event in the simulation window. Name the event and specify the desired outcomes. Enter a frequency or weight for each outcome. Close the window when finished.
  - Choose Edit | Add Outcome or Edit | Delete Outcome to create more or fewer outcomes.
  - Choose Edit | Make Equally Likely to give all outcomes the same frequency or weight.
- Computations: To relate events by a computation first build them so they are added to the simulation model. Next, hold down the shift key as you click to and select the desired events. Choose a computation from the Build menu such as Add, Subtract, Equal, or Combine, or from the Additional Computations entry to relate the selected events.

  Example 1. Choose then then . Click on and hold down shift to select , then choose Build | (Computations) Add. A new event will be created that will read + (8-sided Die + 4-sided Die). The outcome for this combined event will add the value of the 8-sided Die to the value of the 4-sided Die for each run of the simulation.

  Example 2. Choose three times. Hold down the Shift key as you click on each of the digit icons ( ) within the model window. With this selection highlighted, choose Build | Additional Computations | Function. A separate Function Editor window will open describing how each of the selected events are coded (e.g., a:Digit, b:Digit, c:Digit). To relate these events by a function that computes their mean, type (a+b+c)/3 and press Enter (or type average(a,b,c)). A new event that relates the three random digits is listed in the simulation model. Expand or collapse the view (click on the small triangle to the left of the function) to determine which results are displayed in the table and graph.

- Meta Events: To create a Meta Event, first build a simple or custom event so that it is added to the simulation model. Click on the desired event to select it. With the event selected, choose from Build | Meta Events | Accumulate Total, Proportion of, Count Till See, or Count # of.

  Note: Only one Meta Event may be chosen at a time.

  Example. Choose , then Build | (Meta Events) Count Till See. Double-click on the outcome that you are waiting for (this is simulating a waiting-time situation). If you would like to wait for multiple outcomes from one simulation, hold down the Command key and select multiple outcomes.

- Sample Simulations: View a pre-set simulation by selecting it from the Sample Simulations menu.

  Note: When an option from the Sample Simulations menu is chosen it will replace any current simulations. Open a new Simulation window to model multiple situations as separate simulations.

Run a Simulation

After setting up a simulation, use the Simulation menu or their corresponding toolbar buttons to run it.

- Choose to start and stop running the simulation.
- To set the speed of the simulation, select Step, Slow, Medium, Fast, or Fastest in the Simulation menu. Alternatively, the simulation will run one pace faster with each click of the button.

  Note: If the speed is set at a Step pace, click the Go button for each new run.

- Choose to reset or clear all performed runs of the simulation, keeping the same set up or build.

  Note: To clear the build of the simulation choose the button or choose Tool | New.

- Use the Conduct button to do a specified number of runs at once. Each click of the Conduct button will add the specified amount to the total number of performed runs.

Note: The Conduct button does not have an effect on the controls that start, stop, and determine the speed of the runs.

- Choose Edit | Undo to reverse the last action that was performed.

View & Analyze Results

Once your simulation has finished running view or analyze the results.

Viewing Styles and Options

Select (or deselect) entries of the View menu to customize what and how the results of a simulation are shown.

- Choose View | Stacked to display the results in separate tabs. Choose View | Tiled to display results in one window.
- From the View menu, choose from three components of a simulation to view: the Model or build of the simulation, a Table of Outcomes, and a Histogram of results.

  Note: A simulation must be built prior to running it (and both must be done before results will be recorded in the table or graph).

- When a histogram plot is shown, use the View menu to show (or hide): Relative Frequencies (or frequencies), Labels on histogram bars, or a Grid.

  Note: Be sure Graph is selected (checked) within the View menu for these settings to be applied.

Analyze Results

- Choose Edit | Basic Statistics to view the available summary statistics of the simulation outcome(s) in a separate window. These summary statistics include the five-number summary, mean, sample standard deviation, and sample variance.
- Choose Edit | Analyze Results to view the outcome(s) of the simulation within a Data Analysis data sheet.

Save and Record Simulations

The Tool menu provides options for creating new simulations ( ), opening saved simulations ( ), printing ( ), and saving ( ).

See also Save & Print.

Statistics & Probability Custom Apps

The Custom Apps for Statistics & Probability include those for exploring center and spread of univariate data, investigating regression of bivariate data, and randomization and sampling of various distributions. Click on the name of a tool below for a description and help topics:

Univariate Center and Spread

Estimate Center
Estimate Center and Spread

Bivariate Regression

Modeling

Sampling Distributions

Binomial Distributions
Distribution of Sample
Randomization Distribution

Binomial Distributions

Vary the number of successes and the probability of a success on each trial to see how the shape, center, and spread of binomial distributions are affected. Conduct trials and compare theoretical models of distributions to simulation results.

Instructions

Upon opening the custom app, a binomial distribution based on sliders for *n* (number of trials) and *p* (probability of success) is shown. The theoretical binomial model for the parameter values (default: n=50, p=0.5) is displayed in red. The following provide guidelines and tips on how to utilize the capabilities of this custom app:

1. Set up additional binomial situations
2. Customize display settings (optional)
3. Run simulation
4. Tool menu options

Set Up Additional Binomial Situations

Add menu

Select entries from the Add menu to consider multiple distributions at the same time. Values for *n* and *p* are recorded above each distribution as they are added.

> *Help Tip*: Once a distribution is added, distinguish between those that are controlled by sliders and those that are editable by noting the colors of values for *n* and *p*. In particular, values in gray are controlled by the sliders and automatically update the distribution as sliders are dragged. White text boxes with black text are *editable* - first click on the desired one, type an appropriate value, then press Enter to change the corresponding distribution. Editable parameters are not affected by sliders and vice versa.

- Choose Add | Sample Grid to replace any current distributions with a 3-row, 2-column grid of 6 distributions. Each distribution has editable values for both *n* and *p*. Use the Undo button to remove the last distributions, or select from other Add menu entries to add to the grid of distributions.

Help Tip: Notice the sliders for *n* and *p* are hidden because all distributions in the Sample Grid are editable. To access the sliders, Add a distribution based on sliders, or choose Options | Show Sliders.

- Choose Add | Binomial with Editable n to view a distribution for which the value for *n* is editable (type and press Enter to change the entry) while the value for *p* is based on the slider (drag it to change).
- Choose Add | Binomial with Editable p to view a distribution for which the value for *p* is editable (type and press Enter to change the entry) while the value for *n* is based on the slider (drag it to change).
- Choose Add | Binomial with Both Editable to view a distribution for which the values for *n* and *p* are both editable (type into their respective text boxes and press Enter after typing in each one).
- Choose Add | Binomial Based on Sliders to view a distribution for which values for *n* and *p* are based on the values of their respective sliders (drag them to change).

Customize Display Settings (optional)

The default settings for this custom app will Show Theoretical model (in red), Show Sliders for *n* and *p* (useful for distributions based on sliders), indicate the Proportion (as a label along the vertical axis for the histogram), and display a Grid (useful for reading from the distributions). It is not required to change any settings. If desired, access the entries within the Options menu.

Options menu

Select entries of the Options menu to turn them on (checked) or off (unchecked).

- When on Automatically Do Runs is on, the number of runs specified to the right of the Conduct button will automatically be performed as either parameter *n* or *p* is changed. With each parameter change, the distribution is simultaneously reset and replaced with a new binomial distribution based on the updated parameters. Having this option checked when considering distributions based sliders is particularly useful.
- When Show Theoretical is checked, the theoretical model will be shown as a red histogram based on the chosen parameter values for each distribution. Otherwise, this model is hidden.
- Choose Options | Show Sliders to show sliders for parameter values *n* and *p* will be shown as horizontal bars just below the toolbar. Drag a slider to change its value. Otherwise, sliders are hidden.
- When Options | Proportion is checked, the proportion or relative frequency of the total will be displayed above each histogram bar and the vertical axis reflects this labeling scheme. Otherwise, the frequency or number of items displayed will be shown.

  Help Tip: If Options | Label Bars is not checked, individual histogram bars will not be labeled yet the vertical axis labeling will match the appropriate selection as described previously.

- Choose Options | Label Bars to display (or hide) the value for the bar, either its frequency or relative frequency, above each histogram bar.

  Help Tip: When Label Bars is on, individual histogram bars of the theoretical model (in red) are not labeled but histogram bars of conducted simulations are.

- Choose Options | Grid to show (or hide) the grid. Grid display is useful for reading values from the histogram of the distribution(s).

Run Simulation

After setting up the distribution(s), use the Simulation menu or their corresponding toolbar buttons to start, stop, reset, and determine the speed at which runs are performed. Also, use the Conduct button to do a specified number of runs at once. Notice that a tally of conducted runs is displayed at the bottom of the screen.

- *Conduct a Specified Number of Runs at Once*: Enter the desired number of runs in the text box to the right of the Conduct button. Click the Conduct button to perform them at once. Each click of

the Conduct button will add the specified amount to the total number of performed runs.

> Note: The Conduct button does not have an effect on the controls that start, stop, and determine the speed of the runs.

- *Start and Stop*: Use the Go ▶ and Pause ⬤ options to start and stop the runs of the simulation at the specified speed. These buttons do not have an effect on the Conduct button.
- *Set the Speed* ⏩: To set the speed of the simulation, select Step, Slow, Medium, Fast, or Fastest in the Simulation menu. Alternatively, the simulation will run one pace faster with each click of the ⏩ button.

> *Help Tip*: If the speed is set at a Step pace, click the Go ▶ button for each new run.

- Reset ⏮: Choose the ⏮ button to clear all performed runs and restart the simulation using the same distribution set up.

> Note: When Automatically Do Runs is on in the Options menu, drag sliders for *n* and *p* to simultaneously reset and replace the distribution(s) based on the updated parameter values and specified number of runs.

Tool Menu

Choose the information button 💬 to show the summary statistics for the simulation. Additionally, use the Tool menu options or their corresponding toolbar.

- Clear all current distributions and start with a blank screen by choosing Tool | New 📄. Then use the Add menu to consider other binomial situations and their distributions.
- Use the Tools menu to Open (📂), Print (🖨), or Save (💾) a distribution.

> Note: The set-up of the distribution including values for *n* and *p* will be saved; any simulated trials will not be saved. To "Save" the distribution as an image, capture a screen shot of the window. For Mac, press Command+Shift+3. For Windows, press PrtScr.
>
> See also Save & Print.

Distribution of Sample

Explore the shape, mean, and standard deviation of distributions of sample means, medians, or standard deviations for various sample sizes.

Instructions:

1. Set up distribution: choose the distribution type and sample size and customize settings.
2. Run sampling: determine the number of runs and control the speed of sampling.
3. View and analyze results: customize the histogram view and make a data table from sampling.

Set Up Distribution Type and Sample Size Settings

1. *Access Tool and Choose Data Set*
   Choose Distribution of Sample... from the *Data Analysis* Statistics menu.
2. *Select Distribution Type*
   To change the distribution type, select the Distribution of Sample... menu and choose from Means, Medians, and Standard Deviations. Once selected, the population mean/median/standard deviation of the original data is displayed in the bottom-left corner below the histogram window and is also

represented by a red vertical line.

Note: Each time a different distribution type is selected, any performed runs will be reset.

3. *Set Sample Size and Settings*
   To set the sample size, type a value (just below the Controls menu) and press Enter; or move the slider. Listed below are select features of the Options menu used to customize the sampling process. Click here for other settings that are used to customize the histogram view.
   - When Automatically Do Runs is checked in the Options menu, the number of runs specified to the right of the Conduct button will automatically be performed as the sample size is changed. Otherwise, runs will not be conducted automatically. See Conduct and Reset for related help notes.
   - By default, samples are conducted With Replacement. Select this entry of the Options menu to turn this feature off.
   - When checked, Data Columns are shown to the right of the histogram. Select this entry of the Options menu to hide the data columns. NOTE: When runs are conducted at a slow or step pace, the sample data is displayed to the right of the original data at each run and the mean/median/standard deviation of that sample is displayed below the column.

Run Sampling

After setting up the distribution, use the options of the Controls menu or their corresponding toolbar buttons to start, stop, reset, and determine the speed at which runs are performed. Also, use the Conduct button to do a specified number of runs at once. Reference the bottom-left corner below the histogram for a tally of conducted runs and the sample mean/median/standard deviation for the most recent sample.

- *Conduct a Specified Number of Runs at Once*: Enter the desired number of runs in the text box to the right of the Conduct button. Click the Conduct button to perform them at once. Each click of the Conduct button will add the specified amount to the total number of performed runs.

  Note: The Conduct button does not have an effect on the Controls that start, stop, and determine the speed of the runs. However, this value does determine the number of runs when Automatically Do Runs is turned on from the Options menu.

- *Start and Stop*: Use the Go ▶ and Pause ⬣ options to start and stop the runs of the simulation at the specified speed. NOTE: These buttons do not have an effect on the Conduct button.
- *Set the Speed* ⏩: To set the speed of the simulation, select Step, Slow, Medium, Fast, or Fastest in the Controls menu. Alternatively, the simulation will run one pace faster with each click of the ⏩ button.

  Help Tip: If the speed is set at a Step pace, click the Go ▶ button for each new run.

- *Reset* ⏮: Choose the ⏮ button to clear all performed runs at the specified sample size.

  Note: When Automatically Do Runs is checked in the Options menu, change the sample size to simultaneously reset and resample the specified number of runs.

View and Analyze Results

Once the simulation has finished running, view and analyze the results within this tool (included features are in the Options menu) or within Data Analysis (included features are in the Tool menu).

View Data as Histogram

Listed below are select features of the Options menu used to change the settings for the histogram view. See also the Make Data Table help tip for how to view the sampling data in a data sheet.

- Choose Options | Show Relative Frequencies to show (or hide) relative frequencies above each histogram bar and the vertical axis reflects this labeling scheme. Otherwise, the frequency or number of items is displayed above each bar.

  Note: If Options | Label Bars is not checked, individual histogram bars will not be labeled yet the vertical axis labeling will match the appropriate selection.

- Select Options | Label bars to show (or hide) the value for each histogram bar (either its frequency or relative frequency).
- Choose Options | Grid to show (or hide) the grid. Grid display is useful for reading values from the distribution.
- Select Options | Histogram Settings to show (or hide) the customizable options. When shown, type the desired *Minimum x* value and press Enter to adjust the starting value of the horizontal axis. Type the desired *Bin Width* and press Enter (or drag the slider) to adjust the width of each histogram bar.

Analyze Data

The Tool menu provides options for viewing descriptive statistics, making a data table, copying data, printing the distribution, and saving the results.

- Choose Tools | Descriptive Statistics to view summary statistics of the original data and the current distribution based on the total number of runs.
- After producing random assignments of data, choose Tools | Make Data Table to view a *Data Analysis* data sheet containing the sample means/medians/standard deviations for each conducted random sample.

  Help Tip 1: If nothing happens when this option is chosen, most likely the Data Analysis window was closed. To retrieve the data, use the Copy Data to Clipboard option of the Tool menu and choose Paste within a new Data Analysis data sheet.

  Help Tip 2: Choose Edit | Enable to change or alter the results in any way.

- Choose Tool | Copy Data to Clipboard to temporarily store the results of the samples. To view the stored results, open a data sheet within Data Analysis and click in an empty cell. Choose Paste from the Edit menu or the button. The copied data will fill the selected cell and extend to other cells below it.
- Choose to Tool | Print ( ) or Tool | Save ( ) to print or save the histogram as an image (.gif).

  Help Tip: To save the calculated results of a distribution, choose Tool | Make Data Table. Then save the results as a text file (extension ".txt") from within Data Analysis.

  See also Save & Print.

Estimate Center

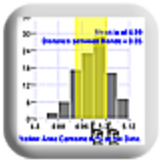
Estimate the mean of a distribution by finding the balance point of the histogram.

Instructions:

1. Using your mouse, move the cursor over the hand at the bottom of the Histogram Plot(s) window. (Notice that *without* clicking your mouse, the position of the hand moves with your mouse.)
2. Estimate the mean of the data set and click once to fix the hand at your estimate.
3. If you located the mean, the histogram will appear balanced (perfectly horizontal), and the value

of the mean will appear in the upper-right corner of the screen.
4. Otherwise the histogram will appear tilted. To balance the histogram, drag the hand until the histogram is balanced (it will be perfectly horizontal).
5. Reopen the custom app to reset it.

See the Histogram entry in the Data Analysis help for further information about the Histogram Plot(s) window.



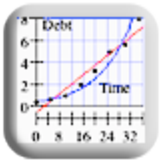
Estimate Center and Spread

Estimate the mean of a distribution by finding the balance point of the histogram and estimate the spread of the distribution.

Instructions:

1. Using your mouse, move the cursor over the hand at the bottom of the Histogram Plot(s) window. (Notice that *without* clicking your mouse, the position of the hand moves with your mouse.)
2. Estimate the mean of the data set and click once to fix the hand at your estimate.
3. If you located the mean, the histogram will appear balanced (perfectly horizontal), and the value of the mean will appear in the upper-right corner of the screen.
4. Otherwise the histogram will appear tilted. To balance the histogram, drag the hand until the histogram is balanced (it will be perfectly horizontal).
5. The hand indicating the mean will remain fixed and a new hand will appear. Move the new hand by moving your cursor to the left or right of the mean.
6. If the distribution is approximately normal, you can estimate the standard deviation. By dragging the hand, find the middle 2/3 (67%) of the data set (the yellow shaded area), and then click. The shaded area can be adjusted by moving the appropriate hand.
7. Reopen the custom app to reset it.

See the Histogram entry in the Data Analysis help menu for further information about the Histogram Plot(s) window.



Modeling

Estimate a curve of "best-fit" on a scatterplot and compare to the regression equation.

Instructions:

1. *Choose an appropriate type of model for estimating regression.*
   Examine the scatterplot of data to determine the best type of regression model for given data set. Click on the Models menu and select (or deselect) from Linear, Exponential, Power, Logarithmic, Quadratic, Cubic, Quartic, Polynomial, or Enter/Edit a Model.
2. *Estimate the regression model - Draw Moveable Line or Model .*
   Choose Draw Moveable Line or Model in the Options menu or click the button. Based on the choice in Step 1, an adjustable model and its corresponding equation will be shown on the scatterplot in green.
3. *Adjust the moveable model to approximate a "best-fit" for the data.*

Drag the left- or right-most green squares along the moveable model to adjust the slope or curve of the model. Drag the green square in the center to move the model vertically or horizontally. Notice the equation of the line updates as the position of the line changes.

4. *Check the reliability of the estimated model.*
   Before drawing the regression model, utilize entries of the Options menu to aid in checking the reliability of the drawn moveable model. For instance, choose Analysis or the X button to show a Residual Plot and Regression Analysis frame.
5. *Draw the regression model - Draw Regression Models*
   With the estimated line is place, compare your estimate to the actual regression line. Choose Draw Regression Models in the Options menu or the button. Notice the regression model will be drawn according to the type of model selected from the Models menu. The line or curve and its corresponding equation will be shown on the plot in blue.

> *Help Tip*: To hide the equations of the moveable model and regression model, uncheck Show Equation(s) by selecting it from the Options menu.

Options menu

Customize how the scatterplot and regression model(s) are viewed in the modeling window. A checkmark next to an entry of the Options menu indicates that is is on or shown, otherwise, it is off or hidden.

- Choose Options | Excluded or the button to exclude (or include) selected data point(s) from the regression analysis. Points are highlighted blue when selected, colored red when excluded, and black when included and not selected. NOTE: If the Show Equation(s) option is on when points are excluded (or included), the regression equation(s) will adjust accordingly, with the most recent equation in blue - the others in red.
- Choose Options | Draw Residuals or the button to show the residuals for each data point.
- Select Options | Draw Squares or the button to show the squared error for each data point.
- Choose Options | Draw Means or the button to draw vertical and horizontal lines representing the means of *x* and *y* data values, respectively.
- When Show Equation(s) is selected from the Options menu, the equations that correspond to drawn estimated and actual regression models will be visible. Otherwise, equations are hidden.
- When Show Predicted Value(s) is selected from the Options menu, a table of predicted values corresponding to all drawn regression and moveable models will appear in a separate window. Click on a table entry and use the arrow keys on your keyboard to move through the table of values; notice the corresponding point and coordinates are highlighted in the scatterplot window. To close or hide the window, choose the X button or uncheck the menu option.

> *Help Tip 1*: A Regression Model and/or Moveable Model must be drawn before predicted values can be shown within the table. The table will automatically update as you show or hide or move these models.
>
> *Help Tip 2*: The Predicted Values table will automatically use the range of x values that are shown in the scatterplot window. Type numerical values into the *Min x*, *Max x*, and *x Step* boxes and press Enter after typing in each box to change these settings.
>
> *Help Tip 3*: To print the entire table of values, resize the window to show all possible values (until there are not scroll bars on the side or bottom); then choose Tool | Print or the button.

- Select Options | Error Thermometer to show (or hide) a depiction of the SSE for the drawn models to the right of the scatterplot. This option is useful when comparing the SEE of the moveable model with the SEE of the regression model.
- Choose Options | Guess Correlation or the button to show (or hide) the guess correlation bar to the right of the scatterplot. Select your guess for *r* from one of the five options available then click **Show r** to view the actual correlation value.
- Select Options | Plot Information or the button to show (or hide) scatterplot information with customizable options. Options include those for modifying labels for *x* and *y*, viewing basic

statistics for the plotted data, naming the plot (or title), and adjusting window settings. Additionally, you may check options to Show Correlation, Show SEE, and Show Confidence Bands.

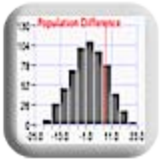
> *Help Tip*: Press Enter on the keyboard to execute any changes made to the name or window scale of the scatterplot.

Tool menu

Use the Tool menu options or their corresponding toolbar icon to:

- View Basic Statistics for the plotted data, which displays a summary of statistical calculations related to the data set.
- Print or Save the current model as it is shown on the screen.

> Note: Files are saved as images, the .gif filename extension is appropriate. Also, the data set used to generate the scatterplot can be saved from within Data Analysis.
>
> See also Save & Print.



Randomization Distribution

Create an approximate sampling distribution of possible differences in means, medians, or standard deviations of two treatments by re-randomizing, then identify extreme events.

Instructions

1. Set up distribution: assign treatments for the chosen data and set the distribution type.
2. Run random assignments: determine the number of runs and the speed at which they are performed.
3. View and analyze results: customize the histogram view and make a data table from the distribution.

Set Up Distribution

1. *Choose Data Set and Assign Treatments*
   Recommended pre-set data choices include: Smell Test, Penny Stacking, Plant Growth, Instructor Attributes, Baby Boys Walking. Alternatively, enter your own data into a Data Analysis data sheet then choose Statistics | Randomization Distribution. Assign a column/treatment number (1 or 2) to two of the columns of data from the chosen set. Click OK to open the tool.
2. *Select Distribution Type*
   To set the distribution type, select the Randomization Distributions menu and choose from Difference in Means, Difference in Medians, Difference in Standard Deviation. The population difference of the original data, (*column 1 mean/median/std.dev.* - *column 2 mean/median/std.dev.*), is displayed in the lower-left corner below the histogram window and is also represented by a red vertical line.

   > Note: Each time a different distribution type is selected, any performed runs will be reset.

3. *Customize Histogram Settings*
   Choose Options | Histogram Settings to show (or hide) the histogram settings. When shown, type the desired *Minimum x* value and press Enter to adjust the starting value of the horizontal axis. Type the desired *Bin Width* and press Enter (or drag the slider) to adjust the width of each histogram bar.

Run Random Assignments

After setting up the distribution, use the options of the Controls menu or their corresponding toolbar buttons to start, stop, reset, and determine the speed at which runs are performed. Also, use the Conduct button to do a specified number of runs at once. Reference the lower-left corner below the histogram for a tally of conducted runs and differences in mean/median/std.dev. for the most recent random assignment.

- *Conduct a Specified Number of Runs at Once*: Enter the desired number of runs in the text box to the right of the Conduct button. Click the Conduct button to perform them at once. Each click of the Conduct button will add the specified amount to the total number of performed runs. NOTE: The Conduct button does not have an effect on the Controls that start, stop, and determine the speed of the runs.
- *Start and Stop*: Use the Go ▶ and Pause ⬤ options to start and stop the runs of the simulation at the specified speed. Note: These buttons do not have an effect on the Conduct button.
- *Set the Speed* ⏩: To set the speed of the simulation, select Step, Slow, Medium, Fast, or Fastest in the Controls menu. Alternatively, the simulation will run one pace faster with each click of the ⏩ button.

  Help Tip 1: If the speed is set at a Step pace, click the Go ▶ button for each new run.

  Help Tip 2: If the speed is set at a Step or Slow pace, notice the messages displayed horizontally on the lower-left of the screen. Additionally, notice that each run value (difference in means, medians, or standard deviations) is determined from a random assignment of color-coded data values from Columns 1 and 2 into one of the two columns.

- *Reset* ⏮: Choose the ⏮ button to clear all performed runs and restart the simulation using the same data set.

View and Analyze Results

Once the simulation has finished running, view and analyze the results within this tool (included features are in the Options menu) or within *Data Analysis* (included features are in the Tool menu). Choose the Save button 💾 to view the difference in means data in the *Data Analysis* window. The File menu option to Save is for the histogram, not the data values.

Options menu

Use the features of the Options menu to customize the settings for the histogram and data columns. Select or deselect entries of this menu to turn them on (checked) or off (unchecked).

- Choose Options | Relative Frequencies to display or hide the relative frequencies above each histogram bar. The vertical axis will also update to reflect this labeling scheme. Otherwise, the frequency or number of items is displayed above each bar. Note: If Label Bars is not checked, individual histogram bars will not be labeled yet the vertical axis labeling will match the appropriate selection.
- Choose Options | Label bars to show (or hide) the value for the bar, either its frequency or relative frequency, above each histogram bar.
- Select Options | Grid to show (or hide) the grid. Grid display is useful for reading values from the distribution.
- Select Histogram Settings in the Options menu to show the customizable options. When shown, type the desired *Minimum x* value and press Enter to adjust the starting value of the horizontal axis. Type the desired *Bin Width* and press Enter (or drag the slider) to adjust the width of each histogram bar.
- Choose Options | Show Data Columns to show the data to the right of the histogram. When

shown, the original data is color-coded; the original data assigned to column 1 is red, and the original data assigned to column 2 is blue. The left-most column gives the original data list, while the middle and right-most columns display the randomly assigned data as runs are performed.

Tool menu

The Tool menu provides options for viewing descriptive statistics, making a data table, copying data, printing the distribution, and saving the results.

- Choose Tool | Descriptive Statistics to view summary statistics of the original data and the current distribution based on the total number of runs.
- After producing random assignments of data, choose Tool | Make Data Table to view the calculated differences in means/medians/standard deviations for each random assignment in a data sheet within Data Analysis.

  Help Tip 1: If the Data Analysis window was closed when this option was chosen, you will not be able to view the results. Be sure to keep the original Data Analysis window open if it is desired to utilize this functionality. Otherwise, choose Tool | Copy Data to Clipboard then open a new Data Analysis window to paste the results into.

  Help Tip 2: Choose Enable in the Edit menu of Data Analysis to change or alter the results in any way.

- Tool | Copy Data to Clipboard to temporarily store the results of the random assignments. To view the stored results, open a data sheet within Data Analysis and click in an empty cell. Choose Edit | Paste or the button. The copied data will fill the selected cell and extend to other cells below it.
- Choose Tool | Print to print the histogram of the distribution.
- Choose Tool | Save Histogram to save the histogram of the distribution as an image. Alternatively, choose the button to send the data of the distribution to the main Data Analysis window for further analysis.

  Help Tip: To save the calculated results of a distribution, choose Tool | Make Data Table. Then save the results as a text file (extension "**.txt**") from within Data Analysis. This is equivalent to choosing the button.

Statistics & Probability Index

All help topics that are available within the Statistics & Probability strand of tools are listed below in alphabetical order.

See also Algebra & Functions Commands.

Add Outcome
Analysis
Analyze Results
Basic Statistics (Simulation)
Binomial Distributions
Box Plot
Build Simulation
Chi-Square Test
Column Formula
Column Name
Common Events
Computations
Conduct
Copy
Custom Apps
Custom Events
Cut
Data
Data Analysis
Data Sheet
Delete Outcome
Descriptive Statistics
Distribution Events
Distribution of Sample
Draw Means
Draw Moveable Model
Draw Regression Model
Draw Residuals
Draw Squares
Edit Styles and Settings
Enable
Enter/Edit a Model
Error Thermometer
Estimate Center
Estimate Center and Spread
Excluded
Fast
Fastest
Fill Down
Frequency Table Graph
Goodness of Fit
Graph (Simulation)
Graphical Displays
Graph menu (Data Analysis)
Grid
Guess Correlation
Histogram
Labels
Make Equally Likely
Matrix Plot
Maximum
Mean
Median
Medium
Meta Events
Modeling
Models menu
N
New
Normal Plot
Paste
Plot Information
Print
Q1
Q3
Random Binomial
Random Normal
Randomization Distribution
Regression
Relative Frequencies (Simulation)
Reset
Run Simulation
Sample Simulation
Sample Standard Deviation
Sample Variance
Save
Scatterplot
Set # of Digits
Show Critical Values
Show Equations
Show Expected Counts
Show Expected Percents
Show Predicted Value(s)
Simple Events
Simulation
Slow
Speed
Stacked
Start
Statistical Analysis
Step
Stop
Table of Results
Test for Independence
Test for Homogeneity
Tiled
Time Series
Undo
View menu
View Results

Advanced Apps

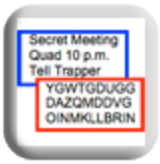
Advanced Apps include tools for exploring advanced topics including vertex-edge graphs, contour diagrams, difference quotients, and cryptography. There are both Discrete and Continuous Mathematical Apps. Click on the name of a tool for a description and additional help topics:

Discrete Mathematical Apps

Vertex-Edge Graphs
Control Charts
Ranked-Choice Voting
Weighted Voting
Codes and Cryptography

Continuous Mathematical Apps

Contour Diagrams



Codes and Cryptography

Encode and decrypt messages using ciphers and cryptography.

Instructions:

1. Input a text message to view it's output and numeric equivalent based on the specified code
2. Use the Text menu to specify what to accept as input. Options include: Numbers (0-9), Letters (A-Z), Letters and Space, Alphanumeric, and Ascii.

   Only the specified text will be encrypted; all other text characters will be ignored.

3. Choose from the Security / Cryptograph menu to vary the model y=mx+b with parameter sliders for m and b. The corresponding graphical and character assignment representations will be updated automatically based on the Simple Cipher that is selected.
4. To get started using the RSA Public-Key Cryptography:
   - Construct: Choose to Generate p and q, or Generate e and d. If you enter your own values, be sure to press Enter.
   - Encrypt and Decrypt: Based on the selected construction (and values of n and d), choose to Encrypt a text message to numbers or Decrypt numbers to characters.

Contour Diagrams

Represent three-dimensional objects and surfaces with contour lines or horizontal and vertical cross sections.

The help topics below include information on: Getting Started and Contour Settings, inserting a

moveable Relief Line whose topographic profile is also displayed, and options for customizing the display of a 3D Graph representing the data.

Getting Started

- Choose Contour Diagrams from the Quick Access | Advanced Apps menu. Alternatively, access *Spreadsheet* and choose Contour / 3D Plot within the Tools | Graph menu. There are options to model a contour diagram from pre-set or user-generated data.

    Create a Contour / 3D Plot from pre-set data: Select from the available Course 4 Unit 6 data sets: NASA Pioneer, Equatorial Venus, Sample C4U6L1. Click OK. A Spreadsheet window for the data and a Geometry window for the contour diagram will appear.

    Create a Contour / 3D Plot from user-generated data: When prompted with data set options, click Cancel (or access a blank Algebra Spreadsheet). Type data values into the spreadsheet cells. Choose Tools | Graphs | Contour / 3D Plot. A separate window with the corresponding contour diagram will appear.

        Help Tip: Type values in a rectangular array of cells in the upper left hand corner of the spreadsheet.

- Reading the tables and contour diagrams.
    - Each numeric value in a spreadsheet cell is represented in its corresponding rectangular grid position on the contour diagram. For example, the value in cell A1 is represented in the upper-left hand corner of the contour diagram grid. Each gridline intersection represents a spreadsheet cell value.
    - Contour lines represent parallel cross sections of an object or surface. When contour lines form closed curves, they are surrounding either a local maximum or local minimum. Most contour lines are labeled according to their elevation.

Contour Settings

- Choose Contour | Controls to change the settings of the contour diagram. Click the X button of the Contour Settings Window to simultaneously close the controls and apply the new settings.
    - *Starting Contour Value*: Type a number for the desired starting contour value for the contour diagram. Any contour line values less than the indicated number will not be shown on the diagram, however, the coloring of the diagram will not change. That is, only the contour lines with values greater than or equal to the specified starting value will be shown on the Contour / 3D Plot.
    - *Contour Spacing*: Type a number for the desired spacing between contour lines displayed on the contour diagram. In general, the lower the contour spacing value (e.g., 0.5) the closer the contour lines will be spaced (i.e., a more fine-grained version of the contour diagram will be displayed).

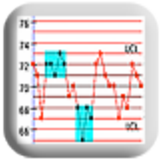
Relief Line

- Choose Contour | Relief Line to display (or hide) a dynamic topographic profile in the lower right-hand corner of the window and the corresponding movable relief line (shown in shades of green across the map). A topographic profile is a vertical cross-section view along a line across a portion of a map.
    - Notice the color of the topographic profile corresponds to the coloring of the contour map.
    - Click and drag near the center of the relief line to change it's position relative to the map. Click and drag an endpoint of the relief line to make the horizontal line oblique or vertical.

Customizable 3D Views

Select entries of the 3D View menu to activate customizable features of the 3D plot. Choose an entry to activate (a check mark will appear next to the entry), select it again to deactivate (indicated by no check mark).

- Choose 3D View | On to turn on a 3D Plot of the corresponding contour diagram.
- Select 3D View | Contour to hide (or show) the contour map. When the contour diagram is hidden and the 3D Plot is On, the 3D graph will appear larger in the viewing window with a x-y-z axis displayed.
- Select 3D View | Draw Grid /Mesh to show (or hide) the grid on the 3D model. Note the 3D Plot must be On for this option to have an affect on the display.
- The Light Source option of the 3D View menu affects the brightness or dimness on the coloration on the 3D rendition of the map. Note the 3D Plot must be On for this option to have an affect on the display.



Control Charts

Examine the run chart for a chosen data set, enter the desired mean and standard deviation, then test for out-of-control behavior.

A run chart or control chart is a plot of data over time organized by a chosen mean and standard deviation to provide a quick, visual check if a process has changed or gone out of control. Some of the methods or tests that industry uses to identify processes that have gone out of control are features of this custom app.

Recommended built-in data sets applicable to *Control Chart* include (but are not limited to): Los Angeles Yearly Rainfall Averages, Apartment Temperatures, Manufactured Nails, and Gas Mileage. Alternatively, enter the desired data set into a *Data Analysis* data sheet, then access Control Chart from the Custom Apps menu.

Instructions:

1. Type the desired Mean and Standard Deviation then press Enter. The mean will be marked at the value indicated, and Zones will be marked off by standard deviations on either side of the mean. The upper control limit (UCL) and lower control limit (LCL) are also indicated, each at three standard deviations from the mean.

   Help Tip 1: To read the chart, consider the placement of data points in relation to the Zone they fall into. For instance, if a data point lies in Zone A, it is more than two, but less than three standard deviations from the mean.

   Help Tip 2: The actual mean and standard deviation are not always the desired choices for setting up a control chart. However, to obtain these values: (1) choose the button for Basic Statistics about the plotted data; or (2) use the Sample Mean and Std. Dev. entry of the Tests menu.

2. Choose from the eight tests listed in the **Tests** menu to identify out-of-control behavior of the data. NOTE: Each of the tests assumes that the individual values come from a normal distribution.

   Help Tip: Make an informed decision about which test(s) to use by examining the data in relation to the indicated Zones and the criteria listed for each test.

3. Depending on the test performed in Step 2, data points may be highlighted that match the identified criteria of that particular test. Otherwise, nothing will be highlighted, indicating no out-of-control behavior.

Summary of Tests:

Test 1 One observation beyond either Zone A.

Test 2 Nine observations in a row on one half of the chart.

Test 3 Six observations in a row steadily increasing or decreasing.

Test 4 Fourteen observations in a row alternating up or down.

Test 5 Two out of three observations in a row on one half of the chart and in Zone A or beyond.

Test 6 Four out of five observations in a row on one half of the chart and in Zone B or beyond.

Test 7 Fifteen observations in a row within the two C zones.

Test 8 Eight observations in a row with none in either Zone C.

Ranked-Choice Voting

Determine voting outcomes based on various ranked choice voting methods.

Instructions:

1. Start by selecting a table from the drop down menu.
2. For pre-set tables, the categories and rankings will be displayed automatically. otherwise, complete a blank table.
3. Choose Vote Analysis to see the results.
4. Select Details for a detailed analysis of each vote analysis method including: Plurality Method, Majority Method, Runoff Method, Pairwise-Comparison Method, Points-For-Preferences Method, and Instant Runoff Voting (IRV) Method.

Weighted Voting

Investigate a voting situation with the Banzhaf Power Index; measure the weight of a voter and determine if their vote is critical or not.

Instructions:

1. Enter a quota.
2. Enter the number of voters.
3. Choose "Go" to assign voter weights to each voter (the number of voters was determined in Step 2).
4. Analyze the results based on the assigned weights. A Banzhaf Power Index (BPI) is assigned for each voter.

Vertex-Edge Graphs

A collection of vertices and edges, draw your own or create sample vertex-edge graphs. Add color, weight, and direction to a graph, run tests and algorithms, and investigate the adjacency matrix representation of a graph.

Vertex-Edge Graphs

A vertex-edge graph is a diagram consisting of a set of points (called vertices) along with segments or arcs (called edges) joining some or all of the points. The positions of the vertices, the lengths of the edges, and the shape of the graph are not essential. Important features of a graph include color, weight, direction, and how vertices are connected by edges.

Drawing Vertex-Edge Graphs

- *Draw Vertices or Edges* : Select the button. Draw a vertex by clicking once in the sketch area. To drawn an edge, hold down the mouse button as you click and drag from the center of a vertex to a new location in the sketch area (or to an existing vertex), release the mouse button. Use these instructions as a guide for drawing a Simple Graph, Multigraph, Directed Graph, Weighted Graph, or Network.

  Help Tip: Use the button to select, edit, move, and make stylistic changes to drawn vertices and edges.

- *Simple Graph*: A simple graph is a graph that has at most one edge (i.e., either one edge or no edges) connecting any two vertices.
- *Multigraph*: A multigraph is characterized by vertices having more than one edge connecting them.

  Help Tip: For two adjacent vertices (i.e., they are already connected by an edge) use the tool to add additional edges connecting them. When drawn, these edges will be slightly bent.

  See also bending edges.

- *Directed Graph*: A directed graph (or digraph) is a graph where the edges have a direction that is indicated by arrows.

  Help Tip: Choose Options | Set Edge Type | Directed before drawing edges or after drawn edges have been Selected .

- *Weighted Graph*: A weighted graph has positive numerical values assigned to its edges.

  Help Tip: To assign weight to individual edges, chose the tool and double-click on a drawn edge. Type a positive numerical value into the text box then press Enter on the keyboard.

  See also Weights.

- *Network*: A network is a Directed graph with Weighted edges.

Pre-Constructed Graphs

Sample Graphs menu

This menu provides pre-constructed vertex-edge graph examples that are organized based on course and by graph type. When a graph is chosen, it will be displayed in a separate window and may be edited and modified if desired.

- *Complete Graph*: A complete graph is a connected graph that has exactly one edge between every pair of vertices. Choose Sample Graphs | Complete Graph to view an example of this type of graph. Type a positive integer for the number of vertices to display in the graph then click OK.
- *Cycle*: A cycle is a vertex-edge graph consisting of a single cycle - a route that uses each edge and vertex exactly once and ends where it started. Choose Sample Graphs | Cycle to view an example of this type of graph. Type a positive integer to specify the number of vertices then click OK to display the graph.
- *Complete Bipartite*: A complete bipartite graph, denoted K*n*,*m*, is a graph consisting of two sets of

vertices, one with *n* vertices and the other with *m* vertices. There is exactly one edge from each vertex in the one set to each vertex in the other set. There are no edges between vertices within a set. Choose Sample Graphs | Complete Bipartite to view an example of this type of graph. Type two positive integers separated by a comma, (e.g. 2, 5), for the number of vertices in each set then click OK.
- *Random*: Choose Sample Graphs | Random to generate a random multigraph according to user specifications (with at most two edges between any particular pair of vertices). First, type in a positive integer for the number of vertices then click OK. Second, type a number between 0.0 and 1.0 representing the probability that an edge should be created.
- *Euler Graph*: An Euler graph is a vertex-edge graph that contains an Euler circuit. An Euler circuit has the property that there is a path that uses each edge exactly once *and* the path starts and ends at the same vertex. Choose Sample Graphs | Euler to view an example of this type of graph.
- *Not Euler Graph*: A non Euler graph is a graph that does not contain an Euler circuit. Choose Sample Graphs | Not Euler Graph to view an example of this type of graph.
- *Euler and Not Euler Generator*: Choose Sample Graphs | Euler and Not Euler Generator to view two Euler graphs and two not Euler graphs at once.
- *P4 v E2 Graph*: Choose Sample Graphs | P4 v E2 Graph to view this graph.
- *Peterson Graph*: Choose Sample Graphs | Peterson Graph to view this graph. One of the interesting features of the Peterson graph is that it has an even number of vertices, all of which have odd degree.

Editing Graphs and Style Options

Once a vertex-edge graph has been drawn (or selected from the Sample Graphs menu) there are various style and edit options that you may choose to utilize. As detailed below, the selection tool, Edit menu, and Options menus are the prominent features available for editing graphs.

- *Selecting Objects*: Choose the Selection Tool to select and move vertices and edges once they have been drawn. This tool is also utilized for many of the style and editing options available in the Options and Edit menus.
- When objects are selected, they will appear highlighted.
  - To select a single object, click on the object once.
  - To add to or take away from an existing selection, hold down the Shift key as you click on each object.
  - To select all objects at once, press the "A" key together with the Command key (Mac OS X) or Control key (Windows).
  - To select a section or multiple objects in the sketch area, click in a clear area and hold down the mouse button (your cursor will change to a "+") as you drag a "box" around all desired objects.
  - To deselect all selected objects, click once in a clear area of the window.
- *Moving Objects*: Choose the button to move vertices and to move and bend edges.
  - *Move a Vertex*: Click in the center of a vertex and hold down the mouse button as you move the mouse (and vertex) to a new location, release the mouse button.

    Note: Any edges that are connected to a vertex will stay connected as it is moved.

  - *Move an Edge*: To change the location or physical length of an edge move the vertices that it is connected to.
  - *Bending Edges*: To bend a drawn edge, hold down the Control key (Mac OS X) or the Command key (Windows) as you click on the edge that you want to bend. A small "repositioning box" will appear where you clicked; select and drag this box to a new location to adjust the curvature or bend of an edge.

Options menu

The Options menu offers various editing options to set edge type, vertex border, and graph display. See

the Adjacency Matrix section for detailed help topics related to adjacency matrices.

- *Add Loop to Vertices(s)*: A loop is an edge that connects a vertex to itself. Select a vertex (or multiple vertices) then choose Options | Add Loop to Vertice(s).
- *Set Edge Type*: Use the Options | Set Edge Type entry to set the edge type of drawn edges to be either Undirected or Directed.
    - *Undirected*: Undirected edges do not indicate direction between vertices. In other words, the edges do not have arrows on them. This is the default graph style.
    - *Directed*: Directed edges have arrows indicating direction from one vertex to another. Choose Options | Set Edge Type | Directed, then all edges drawn after this selection will be directed. Alternatively, Select undirected edges that have already been drawn, then choose Set Edge Type | Directed to show the direction on these edges. The direction is determined based on how the graph is drawn.

        Help Tip: To remove direction from drawn edges Select them and choose Options | Set Edge | Undirected.

- *Set Vertex Border*: Use the Set Vertex Border entry of the Options menu to set the type of border used for vertices.
    - *Circles*: Choose Options | Set Vertex Border | Circles to specify the shape of selected drawn vertices to be circular. This is the default setting that will be automatically applied to all new drawings.

    - *Rectangles*: Choose Options | Set Vertex Border | Rectangles to specify the shape of selected drawn vertices to be rectangular.
- *Set Graph Display*: Use Options | Set Graph Display entry to toggle the weight, color, and degree settings for vertices and edges.
    - *Weights*: Weights are positive numerical values assigned to edges. Choose Options | Set Graph Display | Weights to show (or hide) any user specified or pre-constructed weights. A checkmark next to this entry indicates that any user specified or pre-constructed weights will be shown - this is the default setting.
    - *Name/Add Weight* : Choose the button then double-click an edge, type text (to name) or numbers (to weight) into the text box, then press Enter.

        Help Tip: Add weight to drawn vertices by separating any text and weight with a comma. For example, type Theme, 2 then press Enter. This will be useful for creating your own digraphs to be used with the Critical Path Algorithm.

    - *Colors*: Choose Options | Set Graph Display | Colors to show (or hide) any user specified colors on a graph. A checkmark next to this entry indicates that any user specified colors will be shown - this is the default setting.
    - *Color Vertices or Edges* : To change the color of a vertex or edge to create a colored graph, follow these steps: (1) Select the object(s) you wish to color. (2) Choose the button to view all color options. (3) Click on the desired color then click OK to color all selected objects that color. Alternatively, perform Steps 2-3 then Step 1.
    - *Degrees*: Choose Set Graph Display | Degrees in the Options menu to view (or hide) the degree of all vertices on a given graph. At least one vertex must be drawn before choosing this option.
    - *Degree of a Vertex*: The degree of a vertex is the number of edges touching a vertex. If an edge loops back to the same vertex, that counts as two edge-touchings.

Edit menu

The Edit menu offers stylistic options for existing graphs. Most menu options are also available as toolbar buttons.

- Choose Edit | Undo to reverse the most recent action that you performed. Subsequent execution of this option will continue to reverse previous actions.

    Note: Not all actions can be reversed using the undo feature (e.g., the coloring of vertices or edges).

- Choose Edit | Redo to reverse the action of the Undo button.
- Select an object or objects that you would like to remove. Choose Edit | Cut or the button to remove the selected object(s).
- Choose Edit | Duplicate Graph to produce an exact copy of the currently selected graph.
- Choose Edit | Tile All Windows or the button to view all open windows at once.

    Note: You *cannot* use the Undo option to reverse this action, instead you must resize or use the Scaling Graphs feature as described below.

    - *Scaling Graphs*: To resize or scale a window, use the drop-down menu in the bottom, right-hand corner and select a scale size. Available percentage options are: 25, 50, 75, 100, 200, 300, other.

        Help Tip: The more windows that are open at one time, the smaller they will each be scaled down when tiled, thus the graphs on each window may be harder to see. It may be helpful to only view four graphs at a time in this way.

    - *Alternative Graph Viewing Option*: When more than one window is open at a time, select which one you would like to view by using the drop-down menu at the bottom-middle of the *Vertex-Edge Graph* window. This drop down list contains the names of all open windows.

        Help Tip: The default window name is "Untitled," but this changes to the file name you choose upon Saving.

File Options

The File menu offers options to open, save, and print new and existing work.

See Save & Print for help on Save, Print, and Open options.

- *New versus Clear All*: Choose File | New to create a separate blank window. Alternatively, choose the Clear All button to erase all drawn objects in the active window, without saving.

    Note: Choosing File | New *will not replace or clear* any previously drawn graphs in other windows.

- *Close Window*: Choose File | Close to close the active window *without* saving. Alternatively, you may use the close button (an "X") on the title bar of an individual window to close it.
- *Close All Windows*: Choose File | Close All to close all windows within *Vertex-Edge Graph without* saving.
- Choose File | Exit to quit the tools. Contents of any open windows will be lost unless Saved first

    Help Tip 1: To exit the *Vertex-Edge Graph* tool without quitting the tools use the close button X.

    Help Tip 2: To close individual windows within *Vertex-Edge Graph*, choose Close or Close All in the File menu (or use the close button X on each individual window).

Adjacency Matrix

An adjacency matrix is a matrix representation of a vertex-edge graph in which each entry of the matrix indicates whether the corresponding pair of vertices are connected by any edges (or rather, are adjacent). Each entry of the matrix represents the number of directed edges connecting the *row* vertex *to* the *column* vertex. A zero (0) indicates that the vertices are not adjacent.

- *Display the Adjacency Matrix*: Select Options | Adjacency Matrix to show the adjacency matrix for the drawn graph in a separate window. Click on the cells of this matrix to highlight the corresponding edge(s) on the graph.
- Choose Options | Power of Adjacency Matrix to calculate a specified power of the adjacency matrix

for the drawn graph. A message window will prompt you to enter the desired power that you wish to compute, type a positive integer then click OK to view the matrix in a separate window. Click on the cells of this matrix to highlight the corresponding edge(s) on the graph.
- Choose Options | Distance Matrix to view the distance matrix for a Weighted graph. Each cell of the matrix represents the distance between the column vertex and row vertex. Click on the cells of this matrix to highlight the corresponding edge(s) on the graph.
- Choose Options | Paths of Length n Matrix to display a matrix that shows the number of possible paths of length n that go from the row vertex to the column vertex. Before you are able to view the matrix, a message window will prompt you to enter the desired path length; enter a positive integer value then click OK. Click on the cells of this matrix to highlight the specified path on the graph or to view all possible paths of length n (click on an entry of this list to highlight the path on the graph).
- Choose Options | Adj Matrix to CAS to show the adjacency matrix for the drawn graph in the *CAS* Home and Y= tabs.

Tests & Algorithms

Tests menu

To test a drawn graph or network, choose an option from the Tests menu. A separate message box will display the result of the test. If the test was successful, the message box will list the appropriate vertices used for the chosen test.

- *Connected*: Choose Tests | Connected to determine if the drawn graph is connected. A connected graph is a graph that is all in one piece. That is, from each vertex there is at least one path to every other vertex. If a graph is not connected, the message box will specify how many connected components make up the graph. Additionally, users can click on the drop-down bar to highlight an individual unconnected component.
- *Bipartite*: Choose Tests | Bipartite to determine if the drawn graph is bipartite. A bipartite graph has the property that the vertices can be partitioned into two sets such that every edge connects one vertex from each set. If a graph is bipartite, separate bipartite sets will be highlighted. Additionally, users can choose to display the graph with the bipartite sets separated.
- *Euler*: Choose Tests | Euler to determine if an Euler circuit exists for the graph. An Euler circuit has the property that there is a path that uses each edge exactly once *and* the path starts and ends at the same vertex.

  > *Help Tip*: The Euler test will only display whether or not the graph contains an Euler circuit, it will not tell you what the Euler circuit is. Use the Euler Circuit Algorithm to display what the Euler circuit is.

Algorithms menu

The Algorithms menu offers several different types of algorithms that can be used after a graph or network is drawn. An algorithm is a list of step-by-step instructions or a systematic step-by-step procedure. General instructions for how to run an algorithm are provided below, followed by a list of possible algorithms.

How to Run an Algorithm For a Drawn Graph:

1. Choose Automatic or Step Through in the Algorithms menu to determine the way the algorithm will be completed. A check mark will appear next to the selected option.
   - Automatic: Choose Automatic in the Algorithms menu to automatically carry out and display the final result of the algorithm.

     > *Important Note*: The displayed result of an algorithm may or may not be the only possible result.

   - Step Through: Choose Step Through in the Algorithms menu for the chosen algorithm to be implemented step-by-step with user interaction.

Important Note: Messages with instructions may be displayed in the lower-left hand corner of the screen, or in separate message windows.

2. Select any of the available algorithms that are listed in the Algorithms menu to perform that algorithm on the drawn graph.

   Important Note: Be sure that only one type of procedure and algorithm are selected at once; uncheck any unwanted options by clicking on them.

3. The chosen algorithm will run as Automatic or Step Through (depending on the choice made in Step 1). See below for algorithm-specific help topics.

Algorithms

- *Minimum Hamilton Circuit*: A Hamilton Circuit is a route through a graph that starts at one vertex, visits all the others vertices exactly once, and finishes where it started. The purpose of this algorithm is to find the shortest route (minimum total weight) that meets the criterion of being a Hamilton Circuit.
  - Automatic: The algorithm will automatically highlight the minimum Hamilton Circuit on a graph. If there are two equivalent minimum circuits, a new message window will appear with a drop down menu that will allow you to show each highlighted circuit individually.
- *List Hamilton Circuits*: A Hamilton Circuit is a path that begins and ends at the same vertex and that visits each vertex of the graph exactly once. The purpose of this option is to list all possible Hamilton Circuits of a particular graph. If available, Hamilton Circuits will be organized in an interactive table by weight. Click in the table to highlight a listed circuit on the graph. This option will run the same and produce the same results regardless of whether the Automatic or Step Through option is chosen.
- *Nearest Neighbor*: One purpose to using the Nearest Neighbor algorithm is to find a minimum spanning tree, however, this algorithm is not a guaranteed method for finding a minimum spanning tree. In the Nearest Neighbor algorithm, choose a vertex to start at, and successively add shortest edges without creating circuits, but only add edges that are connected to the vertex where you are at each step.
  - Automatic: The algorithm will automatically highlight a route through the drawn graph and show the result of performing the algorithm in a window. Messages will prompt you to consider whether every vertex has been reached and whether the total weight is minimum. Each iteration of this automatic algorithm may produce a different result, that may or may not produce a minimum spanning tree.
  - Step Through: You will first be prompted to click on a starting vertex on the drawn graph, then select a valid minimum edge. Recall that you must choose edges that are connected (adjacent) to the vertex that you chose. When there are no more edges to be selected, the edge choices and total weight will be displayed in a window. Messages will prompt you to consider whether every vertex has been reached and whether the total weight is minimum. Try starting at different vertices each time you complete this step through algorithm to see what results.
- *Kruskal's Minimum Spanning Tree*: In Kruskal's "best-edge" algorithm, you successively add shortest edges (of least weight) without creating circuits, and any edge you add does not have to be connected to a previously added edge. This algorithm is guaranteed to produce a minimum spanning tree. Note that different runs of Kruskal's algorithm on the same graph could produce different spanning trees.
  - Automatic: The algorithm will automatically highlight a route through the drawn graph and show the total weight of the highlighted edges in a window. Recall that this may not be the only minimum spanning tree for a particular graph.
  - Step Through: Prompts in a message window will instruct you to first select the edge with the least weight by clicking on it on the graph. You will then continue in this manner, choosing the next "valid" edges (as described above). When the chosen edges span the graph (without creating a circuit), the total weight of the selected edges will be displayed.
- *Prim's Minimum Spanning Tree*: In Prim's algorithm, you start at a vertex and successively add shortest edges without creating circuits, and any edge you add must be connected to any vertex already reached. This algorithm is guaranteed to produce a minimum spanning tree. Note that different runs of Prim's algorithm on the same graph could produce different spanning trees.

    - Automatic: The algorithm will highlight a possible route on the drawn graph and display the total weight and order of chosen vertices in a message window. Recall that the shown route may not be the only minimum spanning tree for a particular graph.
    - Step Through: A message window will prompt you to choose a starting vertex by clicking on it on the graph. You will then be prompted to click on "valid" edges (as described above). If you choose an "invalid" edge, check the rules of the algorithm and try again. When the chosen edges span the graph (without creating a circuit), the total weight of the selected edges will be displayed.
- *List Spanning Trees*: A spanning tree is a tree in a connected graph that reaches (i.e. includes or connects) all the vertices in the graph. Note that a connected graph that has no circuits is called a tree. The purpose of this option is to list all possible spanning trees of a particular graph. All possible spanning trees will be listed in an interactive table that lists the edges used (given by vertices; e.g., {A,B} is the edge connecting vertices A and B). Click on a spanning tree to highlight its path on the graph. This option will run the same and produce the same results regardless of whether the Automatic or Step Through option is chosen.
- *Shortest Path*: The purpose of this algorithm is to determine the shortest path between two vertices. First Select two vertices (and no edges), then choose Shortest Path in the Algorithms menu, a message will display the shortest path as an integer value representing the fewest number of edges required to get from one vertex to another. The weight of this shortest path will be displayed once you click OK on the first prompt window. This option will run the same and produce the same results regardless of whether the Automatic or Step Through option is chosen.
- *Critical Path*: A path through a Directed graph (digraph) that corresponds to the earliest finish time is called a Critical Path. Note that it is the length of the longest path that gives the earliest finish time. A good sample graph to use for this algorithm is the Feasibility Study Digraph, found in the Unit 6 Network Optimization option of the Sample Graphs menu. Otherwise, create your own digraph with weighted vertices by separating the text and weight with a comma.
    - Automatic: The algorithm will automatically display the critical path and the total weight of the critical path in a message window. Also notice that the path will be highlighted on the drawn graph.
- *Circuit Finder*: A circuit is a path which begins and ends at the same vertex. Note that a circuit does not necessarily have to make use of every vertex or edge, nor is a circuit restricted to using any particular vertex only once.
    - Automatic: The algorithm will color the edges of each (partial) circuit found. The user can then choose to view a partial circuit from the drop-down list in the message box.
    - Step Through: All edges will initially appear gray in color. Users can click on any edge to show the associated partial circuit by coloring all appropriate edges.
- *Euler Circuit*: If it is possible to start at a vertex and pass along each edge without going over any of them more than once, then the graph has an Euler path. If the path ends at the same vertex at which you started, then it is called an Euler circuit.
    - Automatic: The algorithm will automatically color partial circuits in different colors, both on the graph and in a window with a colored list of vertices. Additionally, an Euler circuit is then traced out by stitching together the colored partial circuits.
    - Step Through: The algorithm will display the partial circuits in different colors on the graph and in a separate window with a colored list of vertices. In another series of windows, click OK to see how all colored partial circuits are stitched together as an Euler circuit is traced out sequentially.
- *Welsh-Powell*: The purpose of this algorithm is to color each vertex starting with a vertex having the highest degree. You then select another vertex of highest degree that is not connected to the previous vertex. You continue doing this until you are required to switch colors, and then the process starts over again.
    - Automatic: The algorithm will automatically color the vertices on the graph and display a window describing the minimum number of colors used and the order in which they were chosen.
    - Step Through: In the bottom-left corner of the main window, a message will prompt you to select the next vertex. Select the appropriate vertices in order according to the algorithm. The program will notify you when a new color is needed for the coloring. The minimum number of colors and an order will be displayed in a separate window when complete.

Help Tip: Choose Options | Degrees before using this algorithm.

Save & Print

In general, the contents of a General Purpose Tool--CAS, Spreadsheet, Interactive Geometry, Data Analysis and Simulation--can be Saved and Printed. See the Help Topics below for more on how to Save, Print, Open, and Capture Screen Images.

Save

A general method to Save a file from a General Purpose Tool is to:

1. Choose File | Save (or Tool | Save) to store a copy of your work to be opened later.
2. Within the Save Dialogue box:
   - Specify the location on your computer to save the file (e.g., Desktop).
   - Name the file using an appropriate filename extension.*
3. Choose Save.

*Note:

Use ".cmt" when saving a file to be opened and modified later (e.g., "MathHW.cmt");
Use ".txt" or ".text" when saving a file to view the programming commands used to create it (e.g., "GeometryCommands.txt", "DataSheet1.txt"); *OR*
Use ".gif" when saving a graph for viewing only (e.g., "functiongraph.gif").

Help Tip 1: If you would like to be able to modify the characteristics of a saved graph, you will have to recreate it from the Data Sheet or Y= tab. Save the Data Sheet or Y= tab contents when you save the graph. Open the Data Sheet or Y= tab contents and recreate the desired plot.

Help Tip 2: Data Analysis, Spreadsheet, and CAS Data Sheets are not saved collectively; only the active data sheet is stored in the file that is saved. Click on each active data sheet to save it individually with an appropriate name.

Help Tip 3: Only the set-up or build of a Statistics & Probability Simulation model will be saved, not specific results. To save the results of a simulation, choose Analyze Results in the Edit menu. Then save the results from within Data Analysis.

Print

A general method to Print material created with a General Purpose Tool or Custom App is to:

1. Rescale the desired window to an appropriate size so that all contents are visible (with no scroll bars).
2. Choose File | Print (or Tool | Print).
3. Within the Print Dialogue Box:
   - Preview the image before printing.
   - Specify the printer and custom print options.
4. Click Print.

Help Tip: If there are difficulties printing, try using the Screen Capture Option first, then printing this digital image.

Open

Two common methods to Open a saved file include:

- Go to the desired General Purpose Tool and choose File | Open . Locate the file on your computer and choose Open. *OR*
- Locate the file on your computer and double-click it.
    - Double-click a saved CMT file to automatically open it within Core Math Tools.
    - Double-click a saved TEXT file to automatically open it within your computer's text editor (e.g., WordPad, TextEdit).
    - Double-click a saved GIF file to automatically open it within your computer's image viewer (e.g., Adobe, Preview).

  Help Tip 1: Double-clicking a saved .txt file will open it in the default text editor program on your computer. From the text editor program you may manually change the commands (for a geometry file) or the data sheet name and column headers (for a spreadsheet file). Additionally, you may open data sheet files from within other spreadsheet programs (e.g., *Microsoft Excel*).

  Help Tip 2: A saved image file (such as a graph with file name extension .gif) will be opened with the default picture viewer program on your computer (e.g., *Picture Viewer* in Windows or *Preview* in Mac OS X).

Screen Capture (Digital Image)

Capture a Screen Image of your work to embed as a digital file within another application, or to print. Two options are given below (the first might not be available from all tools, while the second can be applied at any time).

- Choose File | Copy to Clipboard. Open an application such as Word, TextEdit, or Paint. Choose Edit | Paste (Command+V). The tool image will be inserted as a digital image in this other application. Save, Print, and modify as desired.
- Use the screen capture feature of your computer:
    - Windows--press the "PrtSc" key. Follow an analogous process as the "Copy to Clipboard" option (above).
    - Mac--simultaenously press the keys "Command+Shift+3" or "Command+Shift+4+Space". An image file will automatically be saved to your computer.

Quick Links:

Data Sets

Data sets can be accessed through the Data menu of Data Analysis, the File | Data menu of Spreadsheet, and the File | Data menu of CAS. Click on the name of a Data Set below to automatically download this file and open it within Data Analysis of *Core Math Tools* (an Internet connection is required for file download).

Data Analysis | Data	Spreadsheet | Data	CAS | File | Data

Univariate Data

Categorical Data

2000 State Motorcycle Statistics
Chicago White Sox

Quantitative Data

2000 State Motorcycle Statistics
Achievement Test Scores
Apartment Temperatures
Best Actress
Certificate Perimeters
Concord and Portland Precipitation
Dissolution Times
Fastest Growing Franchises
Gas Mileage
Heights of Young Adults
January Sunshine
Land Use
Los Angeles Rainfall
Manufactured Nails
Mean Hourly Earnings
Min and Max Temperatures
Nickel Weights
Non-normal Distribution
Number of Marriages
Number of Video Games
PSU Women's Heights
Ratings of Movie Showings
Study Time
Sunshine for All Months
U.S. Census 2000 & 2010
Vertical Jumps

Bivariate Data

Categorical Data

Artificial Turf
Bicycle Helmet
Crying
Fashion
Hispanic Origins
IBS and Anxiety
Laptops
Officer Trainees
Seasons
TV Roles
Virginia Crashes

Data Analysis | Data	Spreadsheet | Data	CAS | File | Data

Bivariate Data

Quantitative Data

100-meter Freestyle
AIDS Fatalities in the U.S.
Los Angeles Flight Alt. and Temp.
Major U.S. City Populations

All Manatee Mortalities
Altitude/Atmospheric Pressure
Animal Brain and Body Weights
Baby Boys Walking
Bacteria Growth I
Bacteria Growth II
Baseball Averages
Blood Lead Levels
Braking Road Test
Canines
Car Skid Marks
Chicago White Sox
Cold Surgery
Compact Cars
Crawling Age
Cricket Chirps
Cumulative AIDS Deaths
Dow Jones Averages
DSM Monthly Temps
Federal Minimum Wage
Fertilizing Cost
Flights to/from Chicago
Free Fall Speed
Hamburger Nutrition I
Hamburger Nutrition II
Hamburger Nutrition III
Health and Nutrition
Hippos
Horse Stride
Instructor Attributes
Leg and Stride Length
Light Intensity
Manatee Watercraft Mortalities
Marriage/Divorce Rates
Median Income
Men's 100-meter Run
Mozart/Silence
Non-linear (x,y) Values I
Non-linear (x,y) Values II
Non-linear (x,y) Values III
Peak Cherry Tree Blooming
Penny Stacking
Planet Orbits (km)
Planet Orbits (mi)
Plant Growth
Radioactive Isotope
Radioactive Waste Exposure
Ramp Height and Time
Ramp Time and Distance
Riverdale Adventure Club
Satellite Radio
Seal Sizes
Selected Fast Food
Smell Test
Sphere Radius and Surface Area
Sphere Surface Area and Volume
Surgery Time and Cost
Taking Chances
Tree Age
U.S. Census
U.S. Public Debt
Voters in U.S. Elections
Women's 100-meter Run
World Population

Spreadsheet | Data

Multivariate Data

Quantitative Data

Equatorial Venus
Mars
NASA Pioneer
Terrain Elevations

Catalog

The Catalog is cumulative across the entire suite of tools.

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z Symbols

Strand-specific Indices and Catalogs are available for the general purpose tools:

- *Algebra & Functions*: Commands, Index, CAS, Spreadsheet
- *Geometry & Trigonometry*: Commands, Index, Interactive Geometry
- *Statistics & Probability*: Commands, Index, Data Analysis, Simulation

A
abs()
[abs number]
ans(1)
angle
average()
B
binomcdf()
binompdf()
bisect
C
ceil()
chisqcdf()
chisqpdf()
circle
clear
col()
comb()
complex()
conj()
cos()
[cos number]
count()
cs
D
der()
det()
draw
E
exp()
expand()
F
fact()
factor()
Fcdf()
Fpdf()
floor()
[function expression]
H
halfplane
I
i
id()
imag()
info
input "Prompt" variable
int()
intersection
inv()
invcos()
[invcos number]
invNorm()
invsin()
[invsin number]
invT()
invtan()
[invtan number]
L
let
line
ln()
log()
M
matrix()
max()
midpoint
N
normalcdf()
normalpdf()
P
parallel
path point
perpendicular
perm()
piecewise()
point
polygon
prod()
program
R
ray
real()
S
scale
segment
show
simplify()
sin()
[sin number]
size()
solve()
sqr()
sqrt()
[sqrt number]
stdev()
sum()
T
tan()
[tan number]
tangents
tcdf()
tpdf()
tr()
translate
V
vector
visible
Symbols
+ (add)
@ (at)
/(divide)
= (equal to)
> (greater than)
>= (greater than or equal to)
< (less than)
<= (less than or equal to)
% (modulo)
* (multiply)
!= (not equal to)
^ (raise to the power of)
- (subtract)

reflect
regeq()
root()
rotate
row()

Cumulative Index of Help Topics

All help topics that are available for Core Math Tools are listed below in alphabetical order.

Strand-specific Indices and Catalogs are also available for the general purpose tools:

- *Algebra & Functions*: Commands, Index, CAS, Spreadsheet
- *Geometry & Trigonometry*: Commands, Index, Interactive Geometry
- *Statistics & Probability*: Commands, Index, Data Analysis, Simulation

2D Functions
3D Plots, Bounds
3D Plot Option (CAS)
3D Plot (Spreadsheet)
abs()
[abs number]
Add Outcome
Add Vectors
Adjacency Matrix
Advanced Apps
Algebra & Functions Commands
Alignment
Analysis
Analyze Results
Angle, angle
Angle Measure
Angle Bisector
Animation
Area
ans(1)
Approximate
Auto Numeric
Auto Scale
Auto Simplify
average()
Basic Statistics (Simulation)
Basic Statistics Functions
binomcdf()
Binomial Distributions
binompdf()
bisect
Box Plot
Build Simulation
Calculate, Calculation
CAS
ceil()
Cell
Cell Reference
Center Align
Change Style of Selected
Chi-Square Test
chisqcdf()
chisqpdf()
Circle, circle
Circumference
clear
Clear All (Y=)
col()
Column Formula
Column Name
comb()
Combinatorics Functions
Command Line (CAS)
Command Window (Geometry)
Commands (Algebra)
Commands (Geometry)
Common Events
complex()
Complex Numbers
Computations
Conduct Simulations
conj()
Constructions
Contour (3D Plot)
Contour Diagrams
Coordinates
Coordinate Geometry
Copy
cos()
[cos number]
count()
cs
Custom Apps (Algebra & Functions)
Custom Apps (Geometry)
Custom Apps (Statistics & Probability)
Custom Events
Cut
Data (CAS)
Data (Data Analysis)
Data (Spreadsheet)
Data Analysis
Data Sets
Data Sheet
Default Settings
Default Styles
Define Equation
Degree Mode (CAS)
Degree Mode (Spreadsheet)
Delete Equation
Delete Outcome
Delete Row, Delete Columns
Delete Selected
Delta X
der()
Descriptive Statistics
Deselect All
Design by Robot
det()
Directed Vertex Edge Graph
Distribution Events
Distribution of Sample
Draw, draw
Draw Axes
Draw Grid
Draw Means
Draw Moveable Model
Draw Regression Model
Draw Residuals
Draw Squares
Edit Cells
Edit Equation
Home tab
i
id()
imag()
Implicit
Models menu
Move and Shift Cells
N
New (Simulation)
New Matrix

Edit Formula
Edit menu
Edit Styles and Settings (Data Analysis)
Enable
Enter/Edit a Model
Error Thermometer
Estimate Center
Estimate Center and Spread
Examples (Spreadsheet)
Excluded
exp()
expand()
Explore Angles and Arcs
Explore Radians
Explore Similar Triangles
Explore SSA
fact()
Fast
Fastest
Fcdf()
Fpdf()
Figure or polygon
Fill Down
Fill Color
Filled
Fixed Cell Reference
floor()
Font
Formulas
Frequency Table Graph
[function expression]
Function Iteration
Goodness of Fit
Graph (CAS)
Graph (Simulation)
Graph (Spreadsheet)
Graphical Displays
Graph menu (Data Analysis)
Grid
Grid Style
Guess Correlation
Half Plane, halfplane
Hide Coordinates
Hide Selected
Hide Surfaces
Histogram
info
input "Prompt" variable
Insert Cells
Insert Function
int()
Intersection, intersection
inv()
invcos()
[invcos number]
invNorm()
invsin()
[invsin number]
invT()
invtan()
[invtan number]
Labels (Geometry)
Labels (Histogram)
Left Align
Lengths
let
Line, line
Linear Programming
List of Shapes
ln()
log()
Make Equally Likely
Math Toolbar
Matrices
matrix()
Matrix Editor
Matrix Functions
Matrix Example
Matrix Plot
max()
Maximum
Maximum X, Y
Mean
Measure
Median
Medium
Meta Events
Midpoint, midpoint
Minimum
Minimum X, Y
Mode (CAS)
Mode (Spreadsheet)
Modeling
Normal Plot
normalcdf()
normalpdf()
Options menu (Geometry)
Options menu (Graph)
Options menu (Home)
Options menu (Settings)
Other Functions
Parallel, parallel
Parameter
Parametric Plot Option
Paste
path point
Perimeter
perm()
Perpendicular, perpendicular
piecewise()
Plot Information (Data Analysis)
Plot Style
Point, point
Polar Plot Option
Polygon, polygon
Print
prod()
program
Programming
Q1
Q3
Radian Mode (CAS)
Radian Mode (Spreadsheet)
Random Binomial
Random Normal
Randomization Distribution
Ray, ray
real()
Reflect, reflect
regeq()
Regression
Rectangular Plot Option
Regression
Relative Frequencies (Simulation)
Reset
Right Align
root()
Rotate, rotate
row()
Run Simulation
Sample Matrix
Sample Simulation
Sample Standard Deviation
Sample Variance
Save
Scale, scale
Scatterplot (CAS)
Scatterplot (Data Analysis)
Segment, segment
Select
Select Equation
Set # of Digits (CAS)
Step
Stop
Style Window
sqr()
sqrt()
[sqrt number]
stdev()
sum()
Summary Statistics (CAS)
Summary Statistics (Spreadsheet)
Surface of Revolution
Symbolic Manipulation

Set # of Digits (Spreadsheet)
Set # of Digits (Data Analysis)
Settings
Settings (Home)
Settings (Y=)
Shading
Shift Cells
show
Show Coordinates
Show Critical Values
Show Equation (CAS)
Show Equations (Data Analysis)
Show Expected Counts
Show Expected Percents
Show Hidden
Show Predicted Value(s)
Simple Events
simplify()
Simulation
Simultaneous
sin()
[sin number]
size()
Slice 3D Plot
Slice X, Y, Z
Slicing a Double Cone
Slicing or Unfolding Polyhedra
Sliders, Snap to Mark
Slopes
Slow
Snap to Grid
solve()
Sort
Speed
Split View with Table
Spreadsheet
Stacked
Standard Window
Start
Statistical Analysis
Syntax Error
Synthetic Geometry
Table (CAS)
Table of Results (Simulation)
tan()
[tan number]
Tangents, tangents
tcdf()
Test for Independence
Test for Homogeneity
Thickness
Tiled
Tilings with Regular Polygons
Tilings with Triangles or Quadrilaterals
Time Series
tpdf()
tr()
Transformations
Translate, translate
Triangle Congruence Trig Window
Trigonometric Functions
Undirected Vertex Edge Graph
Undo (Geometry)
Undo (Simulation)
Vector, vector
View Matrix As
View menu (Simulation)
View Options (Graph)
View Results (Simulation)
Visible, visible
Window Scale Y=
Zoom Box
Zoom In
Zoom Out
Zoom Settings
Zoom Sqr
Zoom Std
Zoom Trig

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3D Graphical library (including the pre-build and fully functional algorithms to cut, unfold, truncate, punch and stellate polyhedra): JavaView - Interactive 3D Geometry and Visualization.

3D Custom Apps: www.javaview.de/demo/PaRotation.html
www.fmi.uni-sofia.bg/projects/daad/smbconf_en_nojs/javaview/beograd.html
Plethora of Polyhedra, www.uff.br/cdme/pdp/pdp-html/pdp-en.html

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